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RAILWAY CONSTRUCTION:

FROM

THE SETTING OUT OF THE CENTRE LINE

TO

THE COMPLETION OF THE WORKS;

CONTAINING INSTRUCTIONS FOR

RANGING CURVES AND SETTING OUT LINES AND LEVELS

In Earthworks, Permanent Way, Bridges & Viaducts

ON THE SQUARE, ON THE SKEW, AND ON CURVES.

A TREATISE ON TAKING BORINGS;

WITH PRACTICAL RULES

FOR

DESIGNING WORKS, AND GETTING OUT WORKING DRAWINGS

OF

Masonry and Brickwork, Timber, Wrought Iron
and Cast Iron.

AND

EXAMPLES OF SPECIFICATIONS, AND TABLES
FOR EARTHWORK.

ILLUSTRATED BY 250 PLATES & DIAGRAMS OF EXECUTED WORKS.

BY W. DAVIS HASKOLL,
CIVIL ENGINEER.

VOL. I.

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TO

BERNARD GILPIN, ESQ.,

OF WEDGES MILLS, WALSALL, STAFFORDSHIRE,

I BEG RESPECTFULLY TO

Dedicate

THE FOLLOWING WORK,

As a slight Tribute

OF ESTEEM AND REGARD,

FOR THE ENLIGHTENED VIEWS HE ENTERTAINS

ON ALL ENGINEERING SUBJECTS,

AND OF GRATEFUL FEELING FOR THE MANY KINDNESSES

HE HAS SHOWN TO

HIS SINCERE FRIEND, AND OBLIGED SERVANT,

THE AUTHOR.

PREFACE.

The title of this work will, I trust, sufficiently explain the object I have had in writing the following pages.

They are the result, as regards both field and office work, of various notes, observations, and rules made and applied during a practice of many years in carrying out railway works.

It is now some time since a former work of mine on this subject was published, and received with considerable favour, for which I here request to offer my very sincere thanks. I hope it will not be attributed to vain feelings if I venture to add that it was very favourably reviewed in *The Civil Engineer's Journal*, in *The Builder*, and in *The Artizan;* but that I rather take this opportunity of returning thanks for the kindness then shown to me.

The Diagrams of that work I have made use of in the following pages, and after several years of further practice, I have seen nothing or little to alter; but several most important subjects of railway construction therein discussed have in this new work been treated in a totally different manner, and by entirely new methods, and many subjects which had been wholly omitted are now treated of at considerable length.

Even that peculiarity of human nature which is attributed so freely to those who have the ill-fortune to be infected with *cacoëthes scribendi,* but which I have had very strong reason to be convinced is by no means confined to them, does not lead me to imagine for one moment that the following pages *can* be of great service to the *professed railway* Engineer, but to the student, the practical man, as he is termed, and even to the practised Engineer in other branches of the profession, but who has had no opportunity of carrying out railway works, I hope they will be of use; I think I may venture with safety to add that it is not a work of theory, but of *actual practice.*

To my old, much valued, and esteemed friend, Mr. J. Walter Gale, now in India, I have to return my thanks for his assistance in the practical application of the theory of the arch; nor must I omit to mention that I am much obliged to my young clerk, Mr. Alfred Foley, for the care with which he has prepared the drawings for the engraver, Mr. Jobbins, who has done them that ample justice which he bestows on all engineering and architectural works.

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RAILWAY CONSTRUCTION.

CHAPTER I.

SETTING OUT THE CENTRE LINE WITH OR WITHOUT A THEODOLITE.

Previous to the final setting out of the centre line, the engineer will have to exercise all his judgment and experience in making improvements, and economising the construction of the works by deviating more or less, within the limits of deviation, from the centre line previously laid down. The first step towards effecting this will be a cursory examination of the ground with plan and section in hand. He then forms a rough idea of improvements to be carried out, which may consist in diminishing the quantities of excavation, or a more correct balancing of the cuttings and embankments (keeping in sight what may be required as regards approaches for roads to be raised or lowered); the shortening of a tunnel or a viaduct, or reducing the latter in height; diminishing the expense of heavy bridges by altering their sites; avoiding expensive properties, if possible, or avoiding severance of large and valuable fields. All these matters require a most careful investigation; for, although the Parliamentary line determines the cost, as a grand total, it is surprising how much may be saved by a patient examination of all the conditions and circumstances of the case. Not even the impatience of a Board of Directors to get a start should cause an engineer to overlook, or injudiciously hasten, such an investigation, the neglect of which has caused many expensive errors in railway construction.

The engineer making his notes as he proceeds along the proposed line, from beginning to end, and carefully recording all observations then and there, as they are made, giving particular attention to the all-important subject of drainage, determines on the cross sections he requires. These are always the better for being referred to the general datum line of the whole works.

From these cross sections he readjusts the curves on his plan and the gradients on his section. He finally determines the course of the line, and at the same time, to a very great extent, its merits or imperfections.

This decision made, it is time to set out the centre line. When straight, the stumping out is plain and easy; a few observations will, however, be made about this further on. In ranging out curves care and skill is required, and almost innumerable methods have been introduced. It will only be necessary to mention the two systems now in general use.

For accuracy and despatch, the method of setting out curves at every stump by instrumental observation leaves nothing to be desired, but a good 5-inch theodolite is required.

This method will be described first, (see Fig. 1 in the diagrams at the end of this chapter, which represents a portion of a line of railway on a field plan).

To set out a curve tangent to two straight lines.—On the plan produce the tangent lines, *a* A, and C *c*, and from the plan fix them on the ground as, *a* A B and B C *c*. Plant the theodolite at the intersection B, measure the angle A B C; subtract one half of it from 90 degrees; the remainder will give the angle at the centre, subtended by the arcs A s^4, or C s^4, and which is equal to the *angle of deflection* B A C. Note that the half of this angle of deflection is equal to the angle B A s^4, the angle of deflection of *half* the arc. From a table of natural tangents take the tangent of the angle A B D = to the *angle of deflection* B A C, of the whole arc, or = the angle at the centre subtended by half the arc; multiply this natural tangent by the radius of the curve, the product will give the length B A or B C. Measuring off these lengths on B A or B C, will give the points A and C, at which the curve is to commence or to end. Before removing the theodolite from B, bisect the angle

A B C. From a table of natural secants take the secant of the angle of which you have already taken the natural tangent; that is, A B D or B A C, and multiply it by the radius of the curve. From the product deduct the radius, and measure off the remainder on B s^4, which will give the point s^4 on the curve, and will serve as a check on the stumping out when this point is reached in ranging out the curve.

Ex. Let the angle A B C measure 120°, the half of which subtracted from 90°, leaves 30° for the angle A B D or A B C, or the angle at the centre; and let the radius of the curve to be set out = 40 chains.

Natural tangent of 30 degrees = 0·5773
Radius 40·00 in chains.
Tangent = 23·092000 in chains.

Then 23 chains and $\frac{9}{10}$ of a link measured off from B, towards A and C, will give the exact point from which the curve is to be ranged, and this distance should be chained out with great accuracy.

In the next place, having bisected the angle A B C, and set up a mark, take the

Natural secant of 30 degrees = 1·154
40·00 = Radius.
Secant = 46·16000
Deduct Radius = 40·00
B s^4 = 6·16

Measure of 6 chains, 16 links, on the line bisecting the angle A B C, which will give the point s^4 on the curve.

To ascertain the tangential angle B A s, s A s^1, s^1 A s^2, &c., divide the constant 1718·9 by the radius in chains, which will give the angle in minutes.

Ex. Let the radius be 120 chains; then $\frac{1718{\cdot}9}{120} = 14{\cdot}316 =$ the tangential angle in minutes for a radius of 120 chains. In the case before us the radius = 40 chains. Then $\frac{1718{\cdot}9}{40} = 42{\cdot}972 =$ the tangential angle in minutes for a radius of 40 chains = B A s, s A s^1, &c.

To ascertain the length of the curve in chains, divide the whole angle of deflection by the tangential angle, which will give the length of the curve.

Ex. 30 degrees or 1800 minutes divided by 42·97 = 41·889 = the length of the curve in chains.

To set out the curve, plant the theodolite at A, with the zero on B. Turn the vernier to 42′·97, and chain towards *s*, the intersection will fix this point on the curve; turn the vernier on to twice 42′·97 = 1°25′94, and the intersection will fix the second point s^2 on the curve; turn the vernier on to 42′·97 × 3 = 2°, 8′·91, which will give the third point s^3, on the curve, and so on for 8 or 10 chains, carefully measuring 1 chain forward for each intersection. This distance of 8 or 10 chains may be safely set out at each plant of the theodolite, if it be a good instrument. Suppose 10 chains set out, 42′·97 × 10 = 7°, 9′·7; then the vernier will be at 7°, 9′·7, or 7 degrees, 9 minutes, and $\frac{3}{4}$. Bring it back to 5°,43′,76, the angle for the eighth stump, and then clamp it. Now move the instrument on to the eighth stump. To keep the figure free from confusion by bringing the stump and visual dotted lines too close together, this stump is marked s^3. Having again carefully levelled the instrument, bring the vernier to bear on A, when zero will bear on the tangent T; with the telescope bearing to T, reverse it, and it will then bear with 180° on T^1. Bring the vernier to 182°,8′·91, and if the former work has been correctly done, it will intersect the tenth mark on the curve previously set out. Then bring the vernier to 182°,51′·88, and the intersection will give the eleventh mark, and so on to the end. If, instead of terminating at a chain end, the curve terminates at a fraction of a chain, then the angle last to be set off will be a corresponding fraction; thus for the 89 links over the 41 chains the angle will be 38′·24 instead of 42′·97.

Before leaving the point A, the angle B A s^4 should be measured, if visible from there, remembering that this angle should, in the present case, measure 15°, or one-half of the deflection angle A B D, or B A C. Instead of using ranging poles, it is better to use mere pegs of wood about a foot long, and with the visual line of the telescope always to intersect the peg as near the ground as possible.

Intersection of tangents inaccessible.—Before proceeding any further in this subject, it will be well to examine the case of inaccessibility to the intersection B of the tangents, not an uncommon one, as where this intersection happens to fall in a sheet of water, in the midst of a wood, or a pile of buildings. In Fig. 2, at the end of this chapter, B happens to fall in a sheet of water, and we require the angle A B C, to obtain the angle of deflection or angle at the centre; also we require to ascertain the lengths of the inaccessible distances E B and F B, in order to be able to measure off the lengths of the tangents B A, and B C. In order to do this set off H K and F M at right angles to B C, and G I and E L at right angles to A B, and let these perpendiculars all measure equally 1, 2, or 3 chains, so that lines produced through them to intersect the tangents A B or B C, may clear the obstacle in the way, as at O and P. Now measure the angle I N K, which is equal to the angle A B C, and from which the angle of deflection may be obtained in the way already explained, as also the lengths of the tangents A B and B C. To ascertain the lengths to be measured off on O A and P C, in order to obtain the tangent points A and C, observe that N O, O B, B P, and P N, are all equal; therefore measuring N O, or N P, will give O B and B P. Both N O and N P should be measured, for unless they be equal some error has been committed.

Although this operation is simple enough, still the setting up and measuring off of the perpendiculars, and the sighting out and producing of the parallels, may involve an error unless very carefully done. To check the possibility of this, measure the angles A O K, and C P I, which should be equal; and O N I and P N K, which should also be equal. Note likewise that A O N and O N I should together be equal to two right angles, and the same of H P N and P N K.

These angles and lengths being all found correct, subtract N O = O B from the length of the tangents B A and B C, and set off the remainder on O A and P C, which will give the tangent points A and C; the curve may then be ranged out in the manner already explained.

Should an obstacle intervene on the curve itself, as in the case now before us, where the sheet of water covers a portion of the curve, then pass over 2 or 3 chains, as the case may require, and set off twice or thrice the tangential angle accordingly, until clear of the obstacle. A more important condition under which obstacles may occur on a curve will be examined further on.

The various cases of curves which generally occur are from a straight line into a curve, or *vice versâ*, which we have already examined; a curve running into one of contrary flexure, although, as a rule, this should never occur; always interpose a chain or two or straight tangent; and the case of a curve running into another of similar flexure, but of a different radius, as in Fig. 3 in the same plate as before.

Curves of similar flexure, but different radius.—Let the curve A B C have a radius of 40 chains, and the curve C D E a radius of 60 chains. Consider the curve A B C to have been set out according to the rules already given, and that from the point C we have now to set out the curve C D E, of 60 chains radius. Produce the tangent B C, common to both curves; set out the tangent *e* E, and produce it to the intersection D, from which intersection measure D C, and make D E = D C.

$$\text{Then } \frac{1718\cdot9}{60} = 28'\cdot648 = \text{the tangential angle.}$$

Or at C measure the angle of deflection D C E, and measure the length of the curve C D E, which may be done very nearly, and divide the angle of deflection in minutes by this length of curve, which will give the tangential angle for each chain's length, and set out accordingly.

But suppose that on reaching E the curve does not come in properly. If the tangential angles have been correctly set out, it can only arise from measuring along the chord C E, instead of on the curve. But in the setting out, the length of the curve itself has now been measured, and again dividing the angle of deflection D C E by this new measure of the length of the curve will give the tangential angle exactly.

Therefore when trying to ascertain the tangential angle which will exactly take a curve through a given distant point, this is the method to be pursued.

Ex. Angle of deflection = 15°; length from the starting point to the point to be reached by the curve = 75 chains; 15° = 900′, which divided by 75 = 12′ = tangential angle;

$$\text{and } \frac{1718\cdot9}{12} = 143\cdot24, \text{ radius of curve.}$$

Therefore having the deflection angle and the length of the curve, to find, 1st, the tangential angle, and 2nd, the radius.

Divide the deflection angle by the length of the curve in chains, which will give the tangential angle for each chain's length.

Divide 1718·9 by the tangential angle, which will give the radius of the curve in chains.

Given the direction of two tangents, required to find the lengths of tangents, radii, and deflection and tangential angles of the greatest reverse curves that will connect the two tangents, leaving two chains' length of straight tangent between them; the line to pass through a given point.

Let *a* A and C *c*, Fig. 4, be the tangents of which the direction is given, and P the point through which the curve is to pass.

Measure the angle B A B, and divide this angle by the length of the curve in chains A P, after having measured it, which will give the tangential angle.

By this tangential angle set out the curve A P, and on arriving at P, set out the tangent *t t′*, by the rule given in describing Fig. 1. It will then be seen whether this tangent will strike the tangent C *c* produced far enough from C; if not, set out one or two more chains until the tangent as at *d d* strikes C *c* produced far enough from C.

On this tangent set out a chain or a chain and a half of straight tangent.

Measure *d* O, and make O *c* equal to *d* O.

Measure the angle O *d* C, and divide by the length of the curve *d* C, which, as shown before, will give the tangential angle for setting out the curve.

Given the directions of the tangents a A, *and* C c, Fig. 5; *also the direction of the connecting tangent* B b b′ B′; *required the radii of the greatest curves to connect them, leaving two chains of straight tangent between the two curves.*

At B, measure the angle of A B B′, and subtract one half of it from 90° to obtain the deflection angle.

Take the natural tangent of this angle from the table, and multiply it by the *radius on the plan,* which should give the length to be set off from B to A and from B to *b*.

Next take the natural tangent of half the angle A B *b*, and multiply it by the length B *b*, which will give the correct radius O *b*.

Divide 1718·9 by this radius, which will give the tangential angle for setting out the curve A *b*.

Having set out this curve, plant the theodolite at *b*, with the vernier fixed on the angle of deflection towards A; move round to zero, which will lay out the tangent straight line. Make this equal to one or two chains.

Measure *b′* B′, and make B′ C equal to it.

At B′ measure the angle of deflection as before, which should be equal to C *b′* B′, and ascertain the radius and tangential angle for setting out the curve *b′* C.

Or, having the same tangents A B, B B′, and B′ C, on the ground.

Measure the angle of deflection, equal to 90° minus half the angle A B C.

Set out B *b* = A B.

Measure the length of the curve A *b*.

Divide the angle of deflection by this length of curve in chains, which will give the tangential angle for setting out the curve.

Divide 1718·9 by the tangential angle, which will give the radius in chains.

Having set out this curve up to *b*, there plant the theodolite, with the vernier at the angle of deflection and fixed on A. Move round to zero, which will give the tangent, and reversing the telescope will give the tangent produced, which should be *b b′* B′.

On this tangent measure one or two chains of straight line.

Make B′ C equal to B′ *b′*.

Ascertain the angle of deflection *b′* C B′, and proceed as before.

Inaccessible points or distances.—Let A B C E (Fig. 6) *be a curve, of which the portion of A B C has been set out; but, by reason of a river, or* *steep side of a cliff, the distance C E is inaccessible. To continue the curve from C through E, and onwards towards F.*

Let A be the tangential angle for each chain's length, by which the curve has already been set out from A to C.

Plant the theodolite at C, with the vernier measuring the said angle A × the length of the curve in chains between A and C, and fixed on A; move round to zero, so as to set out the tangent T C; reverse the telescope, which will fix C *t*.

To obtain the length of the distance C *t*. Set out a perpendicular *t* D, which make equal to say one chain; measure the angle D C *t*, and subtract it from 90°, to obtain the angle at D. From the table of natural tangents take out the tangent of the angle D, and multiply it by the length C *t*, which will give the length of the inaccessible distance C *t*.

Divide the square of this length by twice the radius of the curve, and it will give the length of the offset *t* E, which being set off from *t*, will give the point E on the curve.

Now, with the theodolite at E, measure the angle subtended by A C, which, if the work has been done correctly, will be equal to the tangential angle A multiplied by the number of chains in the curve A B C.

By the rule above given, set out the tangent to the curve at E, and proceed setting out towards F.

Ex. Let the tangential angle for each chain's length = 42·97 in minutes, and the radius of the curve = 40 chains.

At C, set out the tangent T *t*; and from *t* set out the perpendicular *t* D = 1 chain.

Measure the angle D C *t*, and say it measures 30°; 90° − 30° = 60°.

The natural tangent to 60° = 1·73, which multiplied by the distance, *t* D = 1·00, gives 1·73 for the chainage of C *t*.

$$1{\cdot}73 \text{ chains}^2 = 13037 \text{ feet};$$

$$\text{twice the radius of } 40 \text{ chains} = 5280 \text{ feet};$$

$$\text{and } 13037 \text{ divided by } 5280 = 2{\cdot}46 \text{ feet for offset } tE.$$

Let the length of curve A B C, already set out, equal 10 chains; and tangential angle = $42'{\cdot}97$; then $42'{\cdot}97 \times 10 = 7^\circ - 9'{\cdot}7$ = the angle subtended by A C, and measured at E, which will prove the work just done.

From E, after having set out the tangential angle for 0·27 chain towards F, proceed as before explained.

Another case of inaccessible distance is where a curve would run through a block of buildings, through the skirts of a wood, or along the edge of a cliff or sheet of water.

At page 5 it has been shown how to overcome this for 3 or 4 chains; but in the case where it occurs for any considerable length, we may proceed by laying out a parallel curve as at Fig. 7.

Let A B C D be a curve of which the portion B C is inaccessible, and let the radius of the curve be 10 chains.

At B set out the tangent T *t*, and make B E, or B F, perpendicular to it, accordingly as the obstacles may be cleared by running the parallel curve E G, or F H. In the present instance, say E G, taking care that B E is made long enough for E G to clear the obstructions.

At E set out the perpendicular K L, parallel of course to T *t*.

By the same tangential angle already used in setting out the portion of the curve A B, set out the parallel curve E G, reducing the chain's length in proportion to the shortened radius.

Say that B E be 3 chains in length; then the radius of the curve E G will be 7 chains in length.

and 10 : 7 :: 1·00 : 70.

Then 70 links will be the length for setting out the stumps along E G.

On reaching the point G, set out the tangent M N; make G C = B E. Set out the perpendicular O P at C, and continue the curves towards D, as before the interruption at B.

Observe that, before any steps are taken towards setting out a centre line, the accuracy of the plan should be tested by measuring a few lines, and comparing with the plan, and by setting out on the ground, from the plan, some well-defined spot; from which take a few angles or bearings, and compare with the plan.

The length of the chain, however good or old it may be, should be carefully tested, and by this length of chain test the plan.

In setting out the chain's length on the ground, mere pegs of wood, about 9 inches or a foot long, are preferable to ranging-rods; care being taken always to intersect the peg with the visual line, close to the ground.

Great care is required that the short tangents produced be really straight lines; the tangents should be carefully measured, and a correct account of the chainage must be kept.

In ranging out straight lines, it is advisable at first to set out these with ranging-rods and by the eye only, and then to fix the instrument on a commanding situation, somewhere near the centre of the line, and moving the instrument a little to the right or the left, get it accurately on the line. After setting out in one direction, reverse the instrument, and set out in the opposite direction. On a line thus set out a careful chainman may then range out such line, chain by chain.

Ranging curves by offsets.—In the two similar triangles, Fig. 8, A O, B O, are radii; A B, a chord; B C, an offset; A, the point of tangency of the curve A B B′ B″ with the straight line T A; and B B′ B″ point on the curve obtained from the lengths of offsets C B, E B′, E′ B″.

$$AO : AB :: AB : BC,$$ for length of offset.

Setting out by chords and offsets.—In practice, produce the straight line to D, making A D = 1, 2, or 3 chains.

Divide the constant 396, the number of inches in half a chain, by the radius of curve in chains, which will give the offset in inches for D B.

Or, divide 33, the number of feet in half a chain, by the radius of the curve in chains, which will give the offset in feet for D B.

Ex. Radius 40 chains.

$$\frac{396}{40} = 9{\cdot}9 \text{ inches.}$$

Or,

$$\frac{33}{40} = 0{\cdot}825 \text{ in feet.}$$

The *tangential* distance B D is not exactly one-half the deflection distance B′ E; but in the practice of ranging out curves it is sufficiently approximate for short lengths. Therefore, take twice B D, for B′ E.

Ex. Let the radius of a curve be 10 chains.

$\frac{396}{10}$ = 3 ft. 3·6 in. length of *first* offset D B, off the tangent A D = 1 chain.

Or, $\frac{33}{10}$ = 3·3 in feet and tenths.

Sight A E through B; make B B′ = 1 chain; make E B′ = D B × 2 = 6′–7″·2.

Sight B E′ through B′; make B′ E′ = 1 chain, and E B″ = E B′ = 6′–7″·2. Continue setting out thus until the tangent point is reached at the other end of the curve. If this be at a full chain, then set out $\frac{6'-7''\cdot 2}{2}$ = 3′–3″·6. If at a fraction of a chain, then a corresponding fraction of 3′–3″·6.

Or we may set out 4 or 5 points on the curve off the tangent.

Setting out by tangents and offsets, Fig. 9.—Observe, that whatever off the tangent,

the offset is	at 1 chain,	B^1, say		1′ – 6″	
then	at 2 chains,	B^2,	it will be	6 – 0	$= 1 - 6 \times 2^2 = 4$
„	at 3 „	B^3,	„	13 – 6	$= 1 - 6 \times 3^2 = 9$
„	at 4 „	B^4,	„	24 – 0	$= 1 - 6 \times 4^2 = 16$
„	at 5 „	B^5,	„	37 – 6	$= 1 - 6 \times 5^2 = 25$

Or, in feet:

at 1 chain	1·5	= 1·5
at 2 „	6·0	$= 1{\cdot}5 \times 2^2$
at 3 „	13·5	$= 1{\cdot}5 \times 3^2$
at 4 „	24·0	$= 1{\cdot}5 \times 4^2$
at 5 „	37·5	$= 1{\cdot}5 \times 5^2$

Suppose *a* A, the tangent, from the point A of which the curve is to start; produce *a* A, onwards beyond B^5.

Calculate the length of the offset, measure off 1 chain A B^1, and set off the offset at B^1, towards C^1.

Lay out another chain B^2, and set off 4 times the offset at C^2;
„ B^3, „ 9 „ C^3;
„ B^4, „ 16 „ C^4;
and so on to B^5.

From B^2, through C^4, set out $B^2 E^3$, which will be another tangent, off which at E^1, check C^5, as $E^1 C^6$ should be equal to 1 offset.

At E^2 set out 4 times the offset;
„ E^3 „ 9 „
and so continue the curve.

To set out a curve without a theodolite; Fig. 10.—Let *a* A and C *c* be the two tangents.

With a box sextant measure the angle A B C, after having produced the tangents to intersect at B.

Subtract half of this angle from 90°, and the remainder will leave the angle of deflection = the angle at the centre subtended by half the curve = to the angle B A C.

This angle of deflection we will call A.

From the table of natural tangents, take out the natural tangent of the angle A, and multiply it by the radius of the curve in chains, which will give the lengths B A and B C, to be chained out towards A and C, in order to have these two points from which the curve is to start and at which it is to end.

Take out the natural secant of the angle A, and multiply it by the radius. From the product subtract the radius, which will give the length of B D.

With the sextant, bisect the angle A B C, and on the bisecting line B D, set out the length B D. D will be a point on the curve.

Next ascertain the length of the curve.—The constant 1718·9 divided by the radius of the curve will give the tangential angle; and the deflection angle A, divided by the tangential angle, will give the length of the curve in chains.

Now, take the natural tangent of half the angle A, and multiply it by the radius of the curve, and set off the product from A to E, on A B, and from C to F, on C B.

Take the natural secant of the angle A, and multiply it by the radius of the curve, and from the product subtract the radius, which will give the length of E d, and of F d^1.

Bisect the angles A E D, C F D, and on the lines bisecting these angles measure off the lengths E d, and F d^1.

There will now be 3 points d, D, d^1, found on the curve.

Take the natural tangent of one-fourth of the angle A, multiply it by the radius of the curve, and set off the product from C, and d^1 to H^3, on the tangent C B; and from d^1 and D to H^2, on the tangent E D F; and from d and D to H^1, also on the tangent E D F; and from A and d, to H, on the tangent A B.

By taking the natural secant of one-fourth of the angle A, and multiplying it by the radius of the curve, and deducting the radius from the product, we shall get the lengths of H s, $H^1 s^1$, $H^2 s^2$, $H^3 s^3$.

By the bisection of the angles, we shall obtain the directions of the lines on which H s, $H^1 s^1$, &c., are to be set off.

We have thus obtained seven points on the curve, besides the points A and C, which will in most cases be found sufficient to be able to lay out the remainder by offsets.

Ex. *To set out the curve* A D C, *tangent to* a A, *and* C c; Fig. 10.

Produce the tangents *a* A, and *c* C, to B.

Measure the angle A B C, which measures, say 105°, half of which subtracted from 90° = 37° — 30′ = the angle at the centre, subtended by D C, or A D, = the angle of deflection, subtended by B C, or A B.

Let the radius of the curve = 30 chains.

The natural tangent of 37° — 30′ = 0·7673.

$$0{\cdot}7673 \times 30 = 23{\cdot}19 \text{ chains} = \text{B A, or B.C.}$$

Natural secant of 37° — 30′ = 1·2605.

$$1{\cdot}2605 \times 30 = 37{\cdot}815$$

$$37{\cdot}815 - \text{radius} = 30 = 7{\cdot}815.$$

$$\frac{105^\circ}{2} = 52^\circ - 30'.$$

At B, set out the angle A B D = 52° — 30′, and check by measuring the angle C B D, also = 52° — 30′.

On B D measure off 7·815 chains, which gives D, on the curve.

And on B A, and B C, measure off 23·019 chains, to get A and C, the tangent points.

To find the length of the curve.

$$\frac{1718{\cdot}9}{30} = 57'{\cdot}2966 = \text{tangential angle for each chain};$$

$$\text{and } \frac{37^\circ - 30}{57'{\cdot}2966} = \frac{2250'}{57'{\cdot}2966} = 39{\cdot}28 \text{ chains} = \text{length of curve.}$$

Now take the natural tangent of 18° – 45′ = half the angle of deflection = 0·3394.

$$0{\cdot}3394 \times 30 = 10{\cdot}182.$$

Make A E, and C F, each = 10·182.

The points F, D, E, will then be on one straight line, and E D, F D, will each = 10·182.

Bisect the angles A E D, and C F D, by making A E *d*, and C F *d′*, each = 71° – 15′.

Take the natural secant of 18° – 45′ = half the angle of deflection, and multiply it by 30, which will give 31·68.

$$31{\cdot}68 - 30 = 1{\cdot}68,$$

which set off from E to *d*, and from F to *d′*, will give the points *d*, *d′*, also on the curve.

In the next place, take one-fourth of the angle of deflection, which will be 9° – 27½.

Natural tangent of 9° – 27½ = 0·1665.

And $0{\cdot}1665 \times 30 = 4{\cdot}995 = AH, = DH^1 = DH^2 = CH^3$.

Measure off these distances, and the points H, *d*, H^1, will be in a straight line, as also the points H^2, *d′*, H^3.

Natural secant of 9° – 27′½ = 1·0137, which × 30 = 30·411.

And

$$30{\cdot}411 - 30 = 0{\cdot}411{\cdot} = H\,s,\ H^1s^1, \text{ \&c.}$$

And 0·411, set off on the line bisecting the angles, will give s, s^1, s^2, s^3, also on the curve.

We have now 8 lengths of curve set out, and each length = 4·909.

We may now proceed with safety to set out the intervening stumps by offsets off the tangents, or the chords produced as already explained. And starting from A.

$\frac{33}{30} = 1{\cdot}1$ offset in feet at 1 chain from A.

and $2^2 = 4 \times 1{\cdot}1 = 4{\cdot}4$ „ „ 2 „
$3^3 = 9 \times 1{\cdot}1 = 9{\cdot}9$ „ „ 3 „
$4^4 = 16 \times 1{\cdot}1 = 17{\cdot}6$ „ „ 4 „

And now referring to figure 9, set out another tangent from B^2, the second chain on the tangent, through C^4, the fourth chain on the curve, and repeat the operation until the curve is set out, checking by the points already set out.

In setting out curves by the method last shown, as perfect accuracy is attainable as by the method with the theodolite, if the following little practical details are observed.

The point B, Fig. 10, will probably be much higher or lower than A or C; and in taking an angle with the box sextant, accuracy depends on the object seen by reflection being in the same horizontal level as the object seen by direct vision. It will, therefore, be necessary to range the lines A B, C B, with the greatest care, so as to bring the ranging rods on these lines much nearer to B, than A and C, and strictly *on these lines;* and to do this the assistants should all be provided with a plumb line and a heavy plummet, by which means also the rods will be set up perfectly upright, which is not a very easy thing to do with the eye only in side-lying ground. The next thing requiring care is the correct measurement of the tangents, when their lengths have been calculated. When these have been so measured, see that the points E, H^1, D, H^2, and F, are all perfectly on one line, as also H, d, H^1, and H^2 d', and H^3.

Observe also that a very obtuse angle, as at E, and F, or at H, H^1, &c., cannot be measured with the box sextant at one sight. But note that the half and the fourth of the angle of deflection is the supplement to the angle A E F, or C F E, or to A H d, D H^1 d, &c.; there-

Fig. 8.

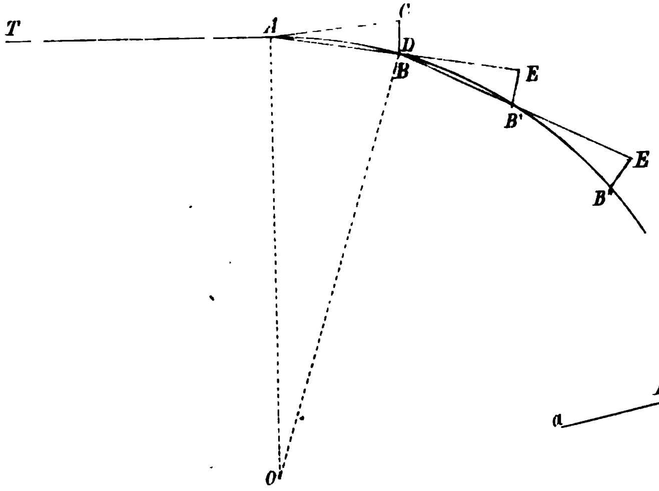
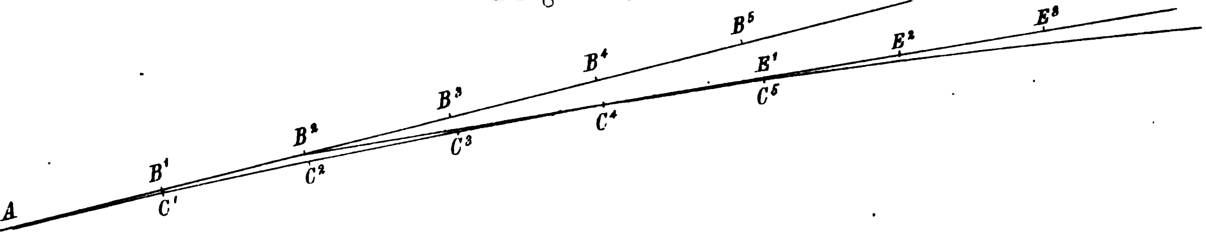


Fig. 9.



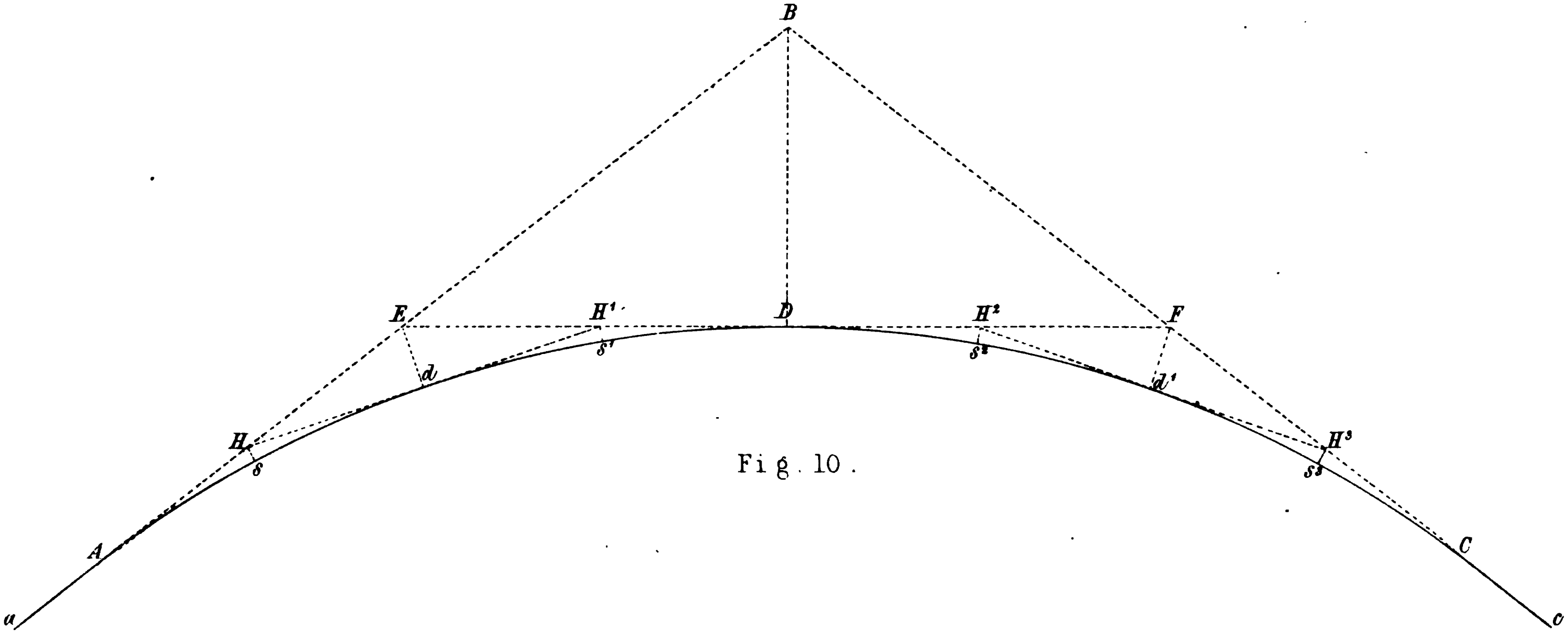


Fig. 10.

Published by Atchley & C° 106 Gᵗ Russell Street, London. April 1857.

J.R. Jobbins.

Fig. 4.

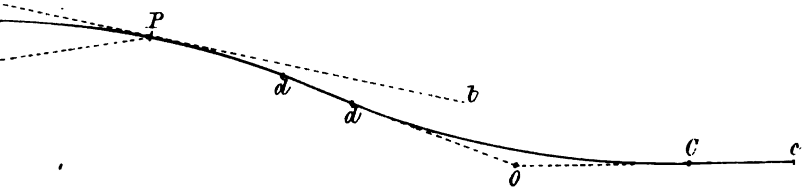
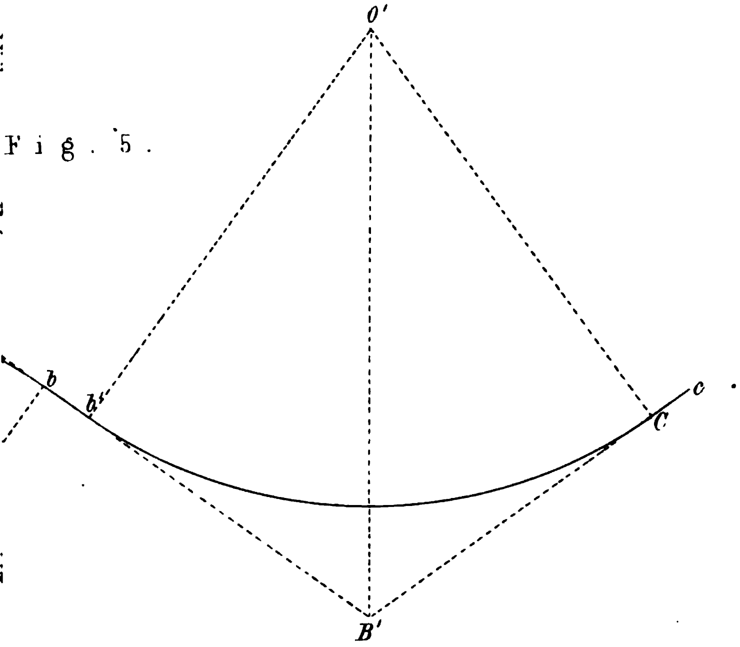


Fig. 5.



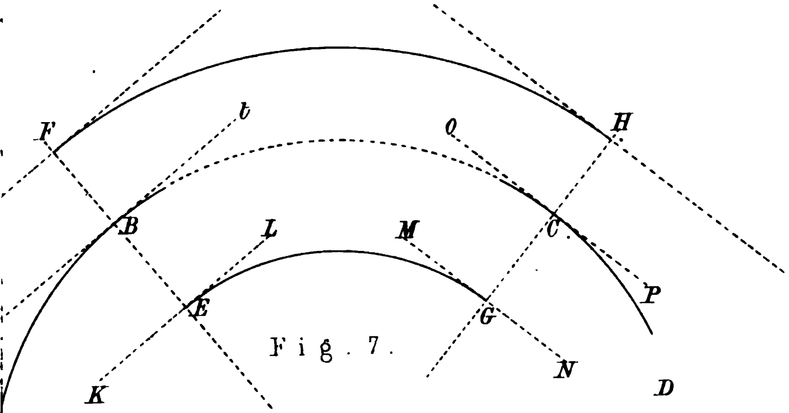
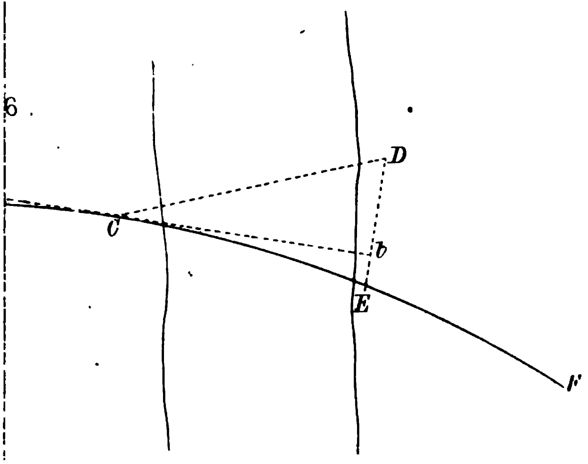


Fig. 7.

6.



fore these angles (one-half, or one-fourth, as the case may be), subtracted from 90°, will give the angle, by which the obtuse angles at E and F, or at H, H^1, &c., are to be bisected.

When a curve has been completely and satisfactorily ranged out, it will be time to *stump out* such portion of the centre line, by driving in stumps, about 2 feet long, and about 2½ × 2½ inches square, in the room of every chain mark; and these stumps had better be driven flush with the surface of the ground, and guide-pegs left alongside of them to indicate the course of the line. Observe also that at every junction of curves, or junction of curves with tangents, a stump should be driven on each side of the centre stump, and these side stumps should be driven slanting, instead of vertical, to prevent mistake.

Straight lines tangent to curves should in all cases be produced, and a stout stake driven in at the intersection, or a stake should be firmly driven somewhere on each of the tangents, so as to be a little out of reach of the works; by means of these stakes, the tangents may at any future time be found, and the curves therefore may also at any future time be set out *exactly* as they originally were.

Nicking out the centre line.—The stumps being all driven in along the centre lines, it becomes necessary to cut a channel along the entire length, which is termed "nicking out;" this channel or nick is made about 6 inches wide, and is formed by cutting out a triangular sod; this sod should be broken up and thrown away, or from motives of mischief it will be replaced. About 1 foot of sod should be left on each side of the stake.

CHAPTER II.

ON BORING; WITH PRACTICAL GEOLOGICAL NOTES.

The engineer and the architect have recourse to the operation termed boring or sounding, to ascertain the nature of the strata of earth or rock which railways, canals, and roads are intended to traverse, on which buildings, viaducts, bridges, and other works are to be founded, to determine the presence and nature of minerals, the direction of galleries in mines, and the construction of subterranean works, to reach springs deeply seated and retained by impermeable strata, and to bring them from many hundred feet below to the surface of the earth, as we see in artesian wells.

For the foundations of important buildings, or for heavy works on diluvial deposits or made soils, scarcely too many borings can be taken to ascertain the nature of materials, as in such cases they often differ much in the area of a few yards; and if heavy walls, piers, or abutments are founded on materials liable to unequal settlement from pressure, or on thin beds liable to slip, or on matter which may be affected by water, fractures and dislocation must inevitably be the result; and, if destruction to the building does not immediately ensue, an unsightly appearance is one sure consequence, independent of the certain knowledge that such work will never bear the test of ages. In railway cuttings and embankments, it is necessary to ascertain most positively the nature of the strata traversed, not only on account of the materials to be removed and employed in embankment, or put to soil as unfit for such purpose; but also with regard to cuttings; for, whilst some rocks will stand with an almost perpendicular face, others, on account of dip, or from loose materials intersecting them, require greater inclination; softer materials, as chalk, indurated sands, strong gravel, will stand at ¾, 1, 1¼, or 1½ to 1, with perfect security, whilst some of the clays will scarcely stand at any slope at all. By a sufficient number of borings, therefore, we ascertain the quantities of land which will be required for the bases of slopes, according to the nature of strata intersected.

The engineer, to whom is confided the operation of taking a series of borings, should be well acquainted with the nature of the various rocks and earths, and if not well acquainted with the sciences of geology and mineralogy, he should at least be able to recognise at sight, or by tests, the different materials brought to the surface; this most useful and practical knowledge can only be obtained by experience, and by the close observation of earths, rocks, and ores, wherever he may meet with them. Unless possessed of this knowledge, he must submit to the inconvenience and mortification of depending on the superior knowledge of labourers and well-diggers; men, however, whose practical experience is never to be despised.

Before proceeding to operations of this kind, the professional man must himself carefully examine all the tools and instruments, see that nothing is wanting, that all is in proper order and repair; and in this, as in all professional matters, let him depend on no one but himself to perform the duties which he owes to his employers.

Mark with care on the plans and sections the places where the borings are to be taken, and the depths which the tools are to reach, or he may afterwards lament having bored in the seat of an embankment, and neglected a cutting. We could cite a case where this occurred to a considerable extent. When it was believed that all the borings were taken, it was found necessary to send another person to take borings that had been totally omitted. Considerable delay, loss of time, and expense were the results.

He must provide a proper register for making notes and observations, remembering that it is his business also to ascertain the form and dimensions of bridges, culverts, and drains extant over streams and rivulets crossing the line.

He must supply a sufficient quantity of sample bags, made of brown holland or similar stuff, to bring back samples of borings, about 6 inches deep by 4 inches wide, or small deal boxes.

The forms of the tools employed vary much, according to the different ideas of those who employ them, and numerous have been the patents taken out for improved, or said to be improved, instruments; we will not attempt a description, nor even an enumeration of these, but will confine our observations to those most generally employed, and the means of using them. They consist of augers, worms, and jumpers or chisels, a 17-feet pricker, the lengthening rods, the head piece or transverse bar, clearing chisels, a claw, a wrench, a fork, a water-can, a hammer, iron pipes, a pick, and two shovels, boards and cleets, scaffolding-poles for triangle, and tackle for hauling up. These implements are carried in a cart drawn by a horse from spot to spot by the nearest route.

The auger is a hollow cylinder of wrought iron steeled, but not too highly tempered, for if brittle the edges will easily break off when they come in contact with flints or other hard substances. The diameter of the auger is 3½ inches, and its substance about ¼ inch in the thickest part. The cylindric part is about 17 inches long; the shank, with the screw to fit into the handle or lengthening rod, is 19 inches; the shank is square, measuring 1⅛ inch on each side; about 7 or 8 threads are sufficient for the screw. This instrument will cut rapidly through soil, loam, chalk, clay, or gravel, if not too coarse, and brings up very perfect specimens of the strata; in lowering it down the hole, and twisting it round, some care must be taken that the cutting-edge be not broken off. Fig. 1, besides being well adapted for general use, will be found particularly useful in bringing up broken stone, &c. Figs. 2 and 3 are particularly adapted to beds of clay, chalk, &c., and Fig. 4 works very rapidly through deep beds of sandstone, when the jumper is not absolutely required. These tools have all the same thickness of shank, and are connected to the rods and handles in the same way.

Fig. 1.

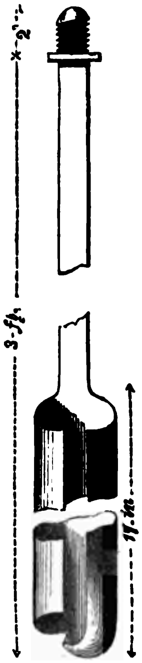


Fig. 2.

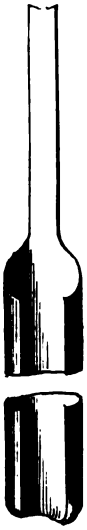
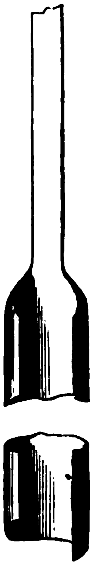


Fig. 3.



The worm, Fig. 5, is from 13 to 18 inches long, and 2½ inches at the broadest part; the substance should be ¼ of an inch at the thickest part; with the shank and connecting screw, it should measure 3 feet 2 inches in length, the same as the former tools. It is used when the progress of the auger is impeded by any hard rock, or sand or limestone, by worming a hole sufficiently wide to receive the bottom of the auger, which then widens the hole and brings up the loosened matter.

Fig. 4.

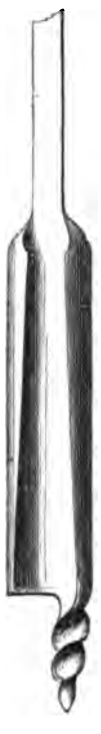


Fig. 5.

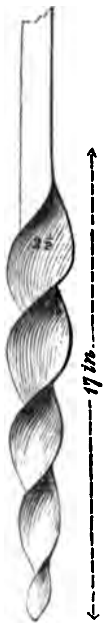
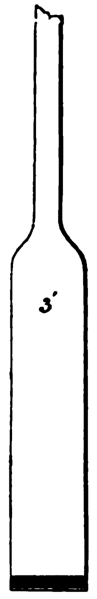


Fig. 6.



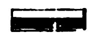
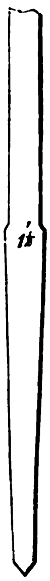


Fig. 7.

Fig. 8.



The jumper is a kind of chisel, employed to break and splinter flints or other hard substances, by which the progress of the auger or worm is impeded; the jumper is then had recourse to, which, by being raised and let fall again, fractures by its weight the impeding matter; when a few blows have been given, the auger is introduced to bring up the fragments. There are two particular kinds of jumpers; the one merely breaks hard substances, the other may also be used to bring up the broken parts. Figs. 6, 7, 8 give elevation, plan, and side view of a jumper, which is no more than a strong chisel, which, being raised and allowed to fall, fractures by its weight, and that of the rod attached to it; the splinters are afterwards extracted by means of the auger. The breadth of this jumper is 3 inches, and the thickness 1½ inch. That at Figs. 9, 10, 11 acts in the same way, but is much heavier. That at Figs. 12, 13, 14 is used in the same manner, and is much employed. The jumper shown at Figs. 15, 16 is a spear, which works with great rapidity in limestone and sandstone, when the rock is rather too hard for the immediate introduction of the auger; this jumper may be used by being raised and let fall, or by turning, to which it is well adapted; if the point happens to be broken off, it can be easily repaired by the nearest blacksmith. The shanks of all these tools are 1⅛ inch square,

Fig. 9.

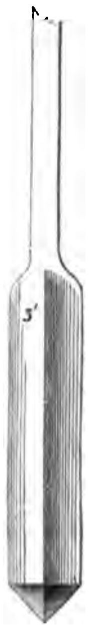


Fig. 11.

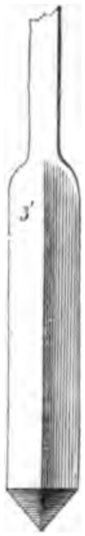


Fig. 12.

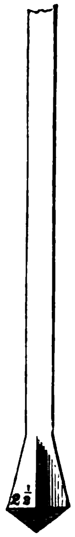


Fig. 14.

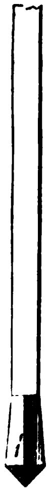


Fig. 15.

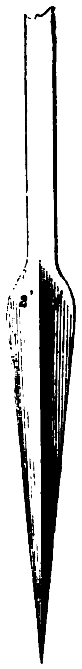
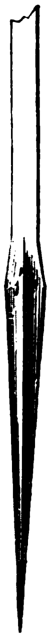


Fig. 16.



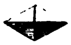


Fig. 13.

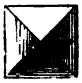


Fig. 10.

each with a flange and screw as in Fig. 1, and they are all 3 feet in length.

FIG. 17.

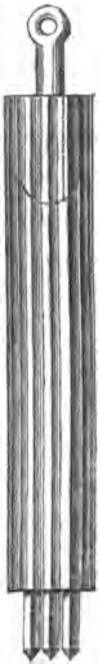
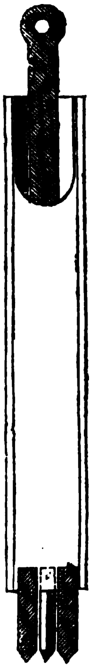


FIG. 19.



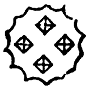


FIG. 18.

Figures 17, 18, 19 give the elevation, plan, and section of a jumper, which is used with a rope instead of lengthening rods, and which is very much employed in deep borings on the continent. When the chisel or spear jumper has been applied by its weight to fracture any hard substance in a bore, and when it has proceeded a certain depth, it is necessary to withdraw it, unshift the jumper, and fix on the auger to extract the splinters; this takes up considerable time. The jumper here described is employed to avoid this loss of time, as by its form it breaks, and at the same time collects the fragments, when they are brought up to the surface. It consists of a wrought iron fluted cylinder, of 3½ inches diameter. There are from 12 to 14 flutes, each of which is about 4 inches deep; at the lower end are four spikes, which serve to break and pierce into the bore; at the top is a cup which collects the coagulated broken materials, and from this cup proceeds a square shank, 4 inches longer than the cup, with an eye to receive a rope. The cylinder, with the spikes, is 2 feet long, the spikes being 3 inches long and ¾ of an inch square. This jumper is lowered down the bore by means of the rope attached to it, instead of rods, and is raised and let fall again about 18 inches or 2 feet, taking care, however, to turn it round every time in the direction of the twist of the rope, to prevent flutes being formed in the rock, which would interfere with the insertion of an auger afterwards; it can thus be raised and lowered 30 or 40 blows per minute; the spikes fracture the rock, and if the bore be kept wet, the splintered and powdered materials, as the spikes proceed, are driven up the flutes and gathered into the cup. When the jumper has been driven a certain number of inches, it is raised by means of the rope, either by hand or by a crab, the magma is scooped out of the cup, the flutes and spikes are cleared out, and the operation recommences. Should any of the spikes be broken off, they are easily renewed, as these screw to about the depth of one inch into the cylinder; they can be forged by any village blacksmith, but it is better to have two or three in store, in case of accident. The rope at the junction with the shank should be occasionally examined, in case it should get worn, when it may be fastened an inch or two higher up. With this instrument alone bores of a very great depth have been executed, and with greater rapidity than with the chisel jumper and auger, to which it has been much preferred.

Fig. 20.

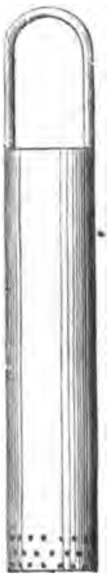


Fig. 21.

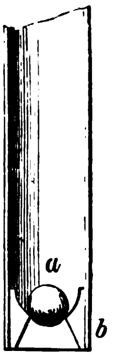
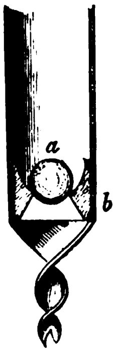


Fig. 22.



Another jumper employed in the same way may be seen at Figures 20 and 21. This consists of a wrought iron hollow cylinder, the casting of which is about ⅛ of an inch in thickness; it is of the same diameter as that just described, and is employed in very soft strata mixed with water; as this jumper is let fall, the material struck drives up the ball *a*, which falling again, prevents it from returning; after two or three falls, it is raised by the rope, and the contents turned out. Fig. 22 shows a similar valve tool, but with a worm, which is exceedingly well adapted for cutting into indurated fine sand; the worm enters this material very rapidly, and the ball being raised by the pressure of the substance wormed out, rises in the cylinder, which, on being hauled up, retains the whole of its contents by this ball closing the aperture. The cylinder may be 1 foot 6 inches long, and the worm about 8 inches; the casing may be of wrought iron, flapped over and riveted. As this instrument is worked into the strata by being turned round, it is attached to a lengthening rod by a screw. With the shank it should measure 3 feet in length. As in Fig. 21, the interior rim *b*, *b*, retains the ball within the interior, and strengthens the lower part of the cylinder. Besides the tools above enumerated, there are a multitude of others: it is not intended to be understood as absolutely requisite that all these should form part of a boring apparatus, but they are all decidedly useful in different earths and rocks.

FIG. 23.

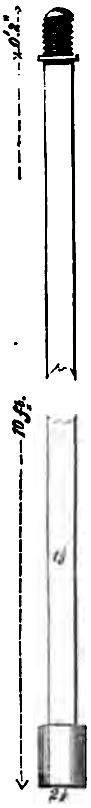
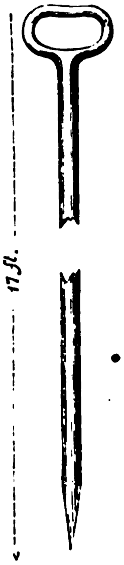


FIG. 24.



The lengthening rods serve to drive the tools lower down as the bore hole is deepened; they are 10 feet long, and the shank is generally square, each side being 1⅛ inch; they are made of wrought iron; at the lower end is a cylindric socket, with a female screw to receive the screw at the top of the tool, and at the upper end is a screw, which fits into the screw socket of the next lengthening rod, when the first has nearly reached as far as the men can conveniently work it; the cylindric socket is 2 inches in diameter, and 2¼ inches long; the male and female screws must all be made of the same length, diameter, and thread; that is, that if any tool or rod be taken up, it must fit and correspond to the socket of any other rod. The rods and tools must be made perfectly straight, and must be kept so, and when fitted together they must form a perfectly straight line. This may be tested by joining them together, and laying them on the ground, when the eye will detect a bend; but better still, by joining together two or three rods, and suspending them by the upper one, when any fault will be easily discerned.

The pricker, Fig. 24, is merely a round iron rod, about 17 feet in length and ¾ of an inch in diameter; it is pointed at one end, and has a ring at the other for pulling it partly out of the ground; it is used in peat or bog, or in soft sands, to ascertain their depth.

The head piece, Fig 25, is a transverse bar, which fixes on the shank of the tool or lengthening rod applied to it, and serves to worm the tools into the ground by being turned round. It is six feet long from end to end. Fig. 26 shows the fixing part of the head piece to one quarter size. It is of wrought iron, as well as the two arms, *a, a,* Fig. 25. In *a,* Fig 26, is fixed the lengthening rod, where it is firmly tightened by a key fixing in the slit *c*; this key, when loose, hangs by a chain in *b,* which prevents its being lost. At the extremity of *a, a,* Fig. 25, are two tangs passing entirely through two wooden handles, *b, b,* with which the men handle the head piece. To tighten and loosen the key a hammer is used.

The clearing chisel or scoop is merely a piece of bar iron of about 15 inches in length, and 1 inch in diameter, flattened at one end, and slightly bent; it is used for clearing out the augers or the worms. The claw, Figs. 27 and 29, is for seizing the rod under the head piece or under the socket, and being then fixed to the rope running over the sheave of the pulley block, the head piece and rods are hauled up. It is entirely of wrought iron. The ring piece A fixes on B, to which it is screwed by the nut screw C, and turns on it. The rod below the head piece, or below a socket, enters and fits into D, and the head piece or socket rests on A, Fig. 28. The opening D is exactly 1⅛ inch,

Fig. 25.

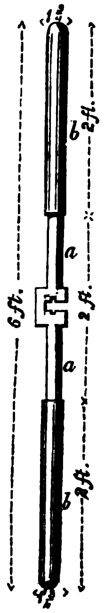


Fig. 26.

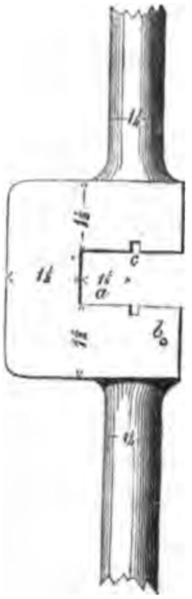


Fig. 27.

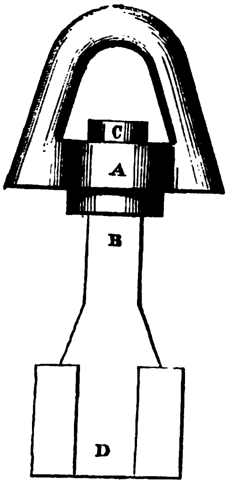
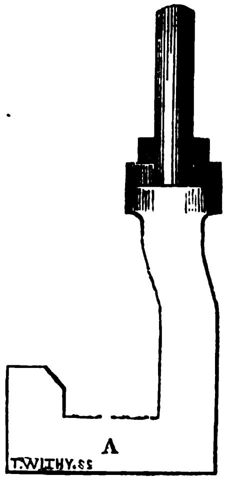
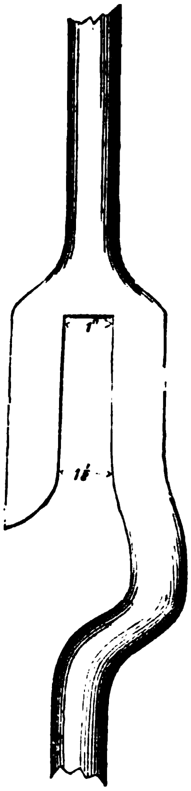


Fig. 28.



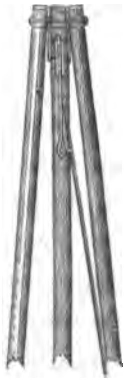
as also the part B. The front and side elevations being drawn to one quarter size, it is presumed that any further explanation is unnecessary. Fig. 29 is a wrench to unscrew the rods or tools; it may be also used to maintain the rods suspended in the bore hole.

FIG. 29.



The triangle may consist of three stout scaffolding poles, of about 25 feet in length, hooped with iron at top and bottom. Fig. 30 shows the manner in which they are fastened at the top. Rope is sometimes used instead of the bolt. An iron of a little greater length than the diameters of the three scaffolding poles is first passed through the centre pole, and over this rod the two rods connected to the sheaf are passed; the two outside poles are then passed over, leaving a little play for the two rods supporting the sheaf. Fig. 31 shows the sheaf and rods to a larger scale. A is the centre pole, B the ¾-inch diameter rod passing through it, as well as through the eyes of the rods CC, which are half an inch in diameter; these being fixed, as we have said before, the outside poles are then fixed and secured; sufficient spread is then given to the triangle to give it a firm standing. The rope should be passed over the sheave before the triangle is raised up, and this rope should often be examined.

FIG. 30.



Previous to commencing boring, it is necessary to dig a hole with the pick and shovel, but the depth of this hole varies according to the depth of the bore; if it is only some 15 or 20 feet, it is sufficient to dig a hole 1 foot deep and 1 foot square, and over it to place a couple of 2-inch planks; the two planks have a semicircular hole in the edge of each, so that when placed side by side the two semicircles together form a circle, and allow the rods and tools to be passed up and down through them, Fig. 32. By the assistance of the hole and this plank platform, it is easy to ensure the perpendicular direction of the tools as they are worked downwards, by jumping or rotation. The hole being dug and the platform fixed, an auger, if the earth is soft, is fixed to a rod and let down through the hole; the head piece is then fixed, and two men taking hold of the bar of the head piece, one at each end, they commence walking round, and the tool works into the earth, exactly as a gimblet works into a piece of wood. Before commencing to turn round, mark with a bit of chalk a scratch on the rod six inches above the platform, and when the tool has sunk so much, the men are to haul it up; the contents of the auger are taken out, carefully examined, noted, and a piece perfectly free from any rubbish is put into one of the bags already mentioned, with a piece of paper on which is written the nature of the soil, and the depth from which it has been extracted. The same remarks are then entered in the register, of which we will give an example hereafter. The tool is then passed through the platform into the hole, a six-inch mark again made, and the work recommences exactly in the same manner as above described. When the auger will not sink any deeper in consequence of the hardness of the substratum, the rod and the auger must be hauled up, and the latter unscrewed, and the worm, Fig. 5, must be screwed on: care should be taken, in removing

FIG. 31.

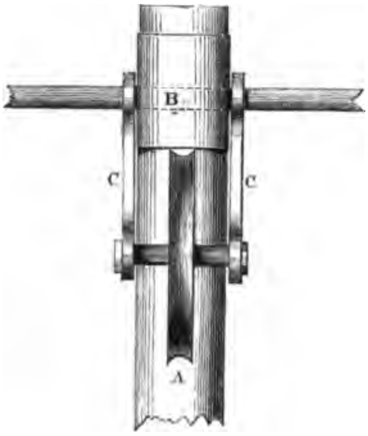
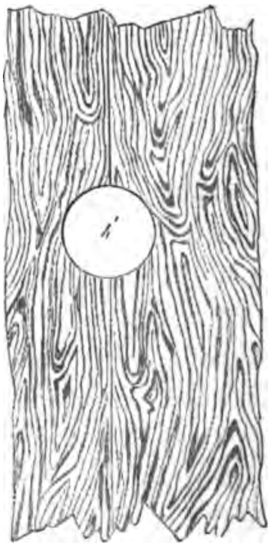


FIG. 32.



one instrument, that no dirt is introduced into the socket. The worm being fixed to the rod, it is allowed to drop gently down in the hole; for if it should be let down suddenly, the tool would break off. By means of the head piece the worm is turned round to work its way through the rock or stone; but if it does not work in, this must also be extracted, the worm be unscrewed, and one of the chisel-jumpers screwed on, and passed down the hole; this is used by raising the rod by the head piece, and allowing it to fall again, which is termed pecking, care being taken to turn it round a little each time, and that not in such a manner as to unscrew the rod from the tool, which would then be left at the bottom of the hole. By making one of the men sit on the centre of the head piece, the worm may be made to cut into very hard rock; but a bed of flints is sure to require the chisel-jumper. When the jumper, after a number of falls, has broken up a certain quantity of rock or flint, it is pulled up, and an auger being screwed on instead and let down the hole, it is turned round by the head piece, it collects the loose matter, and is then hauled up, and, if necessary, the former operation is repeated. Considerable care should be taken in letting down the auger after using the chisel-jumper in beds of flint, of which the splinters are liable to fly, and, by sticking in the sides of the bore, hook up the auger, and prevent its descent or ascent. When one of these splinters is so found, a heavy valve auger is serviceable; as when let down to the required depth, by raising it up or down, it either drives in or down the object in the way.

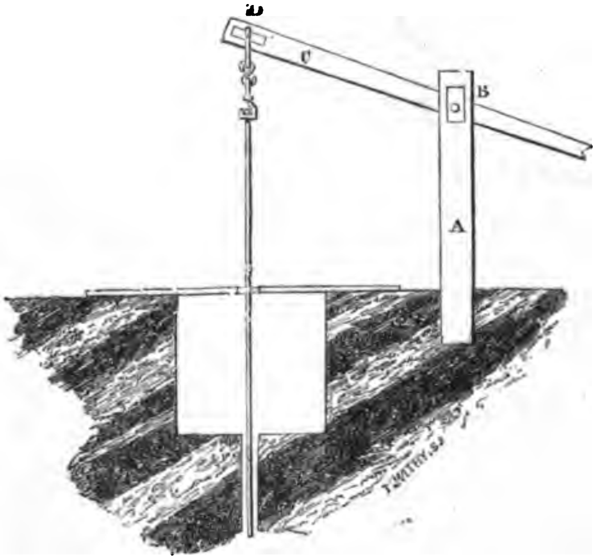
By constant percussion and friction the tools are liable to become much heated and lose their temper; besides which, if dry, the materials to be bored through are much harder. To keep the tools cool, and still more to soften the earth or rock, about a pint of water must be occasionally poured in; this loosens the earth, keeps the tools cool, and helps to make the loosened materials form magma, and therefore form a solid mass in the auger used.

In boring through the tertiary deposits, mosses, and sands, very wet or soft powdery matter is met with, which will scarcely adhere in the common auger, but falls out as the tools are hauled up. In this case, either the valve jumper, at Figs. 20 and 21, or the valve auger at Fig. 22, works well; the first in a soft substance, as sand and water or vegetable matter, whilst, as we have before observed, the latter works rapidly in sands, and it is ascertained whether they are dry or wet, which it is desirable to know. This dry sand would fall out of the common auger, but the ball and socket retain it in the valve auger.

When it is intended to bore beyond 20 feet, we proceed in a rather different manner. A hole of about 3 feet in length, 2 feet wide, and 3 feet in depth is dug, and over this the platform is placed, keeping the hole in the two planks as nearly as possible above the centre of the hole; instead of proceeding as before, it is best to fix the triangle, pass the rope over the sheave, and set up the triangle in its place, placing it so that the apex shall be exactly above the hole, which may be easily done by shifting one of the poles; the rope being lowered with the claw fixed to it, will hang exactly over the hole, if the vertex of the triangle is truly over the centre. The hole we have just mentioned is for the purpose of a lad getting into it, and sitting over the bore during the operation; his business is with the scoop, to clear out the tools, hand up the contents, replace the tool exactly in the bore when it is to descend again. The hole being dry, the boy in his place, the platform fixed, and the triangle set, after, however, noting the contents of excavation, operations commence by fixing, as already stated, a tool to a rod, an auger, if clay or chalk or other material into which it will work, or any tool adapted to the case; it is let down into the hole, the bottom of which it will reach perfectly perpendicular, if a little care be taken, and let it be carefully remembered that this is an important point. The head piece is then fixed and kept at a suitable height above the planking for the men to work, and the work is commenced. The first length of rod may very well be worked by hand without the assistance of the triangle; but when the second lengthening rod is applied, it becomes very serviceable. When the length of rod hauled up exceeds the height of the triangle, the key, Fig. 29, is drawn across the rod, and so as to rest on the platform, and, by being pulled tight, holds the rods suspended; a wrench, an exactly similar instrument, is then applied to the rod, as near a socket as convenient, and of course above the key, and the upper rod unscrewed. The rods hauled up are then placed aside, and the claw is placed under a socket of the length of rod remaining in the bore, and the operation repeated until the whole is brought up, when a change of tool is effected, or the contents of the auger handed up. As we have before observed, samples of the substances thus extracted are put in small bags, with a note of observations, and particularly the number of the bore and the depth. When a great depth is attained, and the chisel-jumper is employed, the great length of rods renders them too heavy to be raised by hand; it must then be done by hauling up with the rope about 18 inches, but not much more, or the tool may break, except, indeed, Fig. 11, which is very strong.

It will now be readily understood that the extraction of the rods after the chisel-jumpers have been used, the insertion of the augers to gather up the fragments of broken material, and then again the extraction of these augers, take up much time, and we do not hesitate in recommending the fluted jumper, Figs. 17 and 19, which is attached to a rope. Obviously the rock must be broken up by the spikes, and if water be kept in the hole, the contents must be forced up the flutes and be gathered into the cup, when they may be much more quickly hauled up than by the manner first described. This jumper may be worked by the men merely pulling at the rope and letting it fall again, turning round, however, about a foot at every four or five falls, for reasons already explained, or it may be worked by a lever, as shown in the Fig. 33.

Fig. 33.



A post A, Fig. 33, about 8 inches square, is driven into the ground about 18 inches; in this post at B, rests the lever C, which is about 12 feet long; at the end D, as shown in the cut, the claw is attached, seizing the rod under the socket, and the lever is worked up and down from the opposite extremity.

When a depth of 70, 80, or 100 feet is reached, as at the entrance of tunnels, and a much greater depth, when boring along and above a tunnel, the weight of the rods becomes too great for the men to manage in the manner before described, and it becomes necessary to have recourse to mechanical assistance, which consists in a crab of a simple construction, and which is used with the assistance of a different species of triangle. It consists of four poles, two of which are built up together. Figs. 34 and 35 will assist in explaining this; Fig. 34 will show the vertex of this stand, and Fig. 35 will show the application of the crab. A A are the two sound poles, free from shakes and flaws, bevelled off at top to fit close, and strapped and bolted together. B is the axle bar, which passes through the eyes of the sheave rods, and afterwards through the two outside poles, which are also strapped to the same depth as the two first, to prevent their splitting. With the two first they form a four-footed stand of extreme solidity; the whole

Fig. 34.

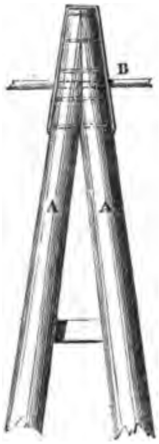
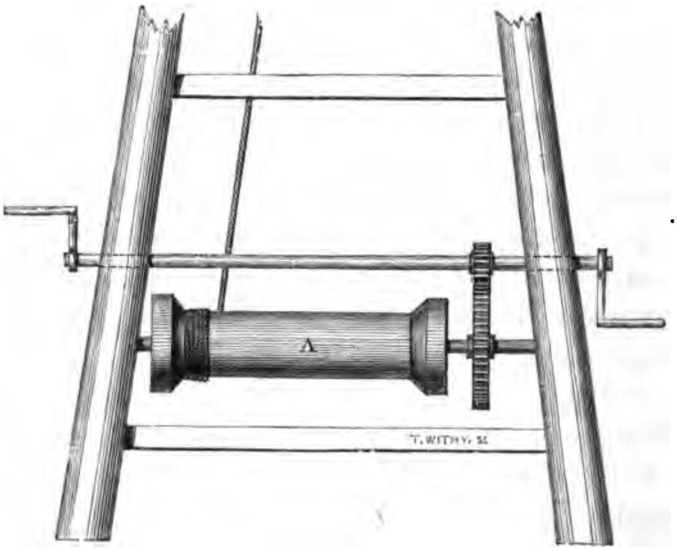


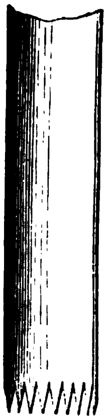
Fig. 35.



should be twice painted in oil lead colour. Fig. 35 shows these two poles at the lower end, with the crab attached. The rope passes over the rope-drum A, from whence it ascends, and passes over the sheave in the vertex of the triangle, and redescends to catch the claw.

We are liable in boring to meet with clays which, being in a comparatively fluid state, are apt to slip or collapse, from the superincumbent pressure of layers we have bored through, or with earths, of which some of the materials are apt to fall in and wedge in the tool employed, when it is often difficult to disengage it. We meet with water which inundates the bore, or if coming from higher grounds, spouts out and impedes the work of the men, or with shifting sands, which partially fill up the hole as fast as it is cleared out. Piping is then required to allow of the prosecution of the boring. The pipes may be of cast iron, and may, in the vicinity of a large foundry, be found all ready; but if made for storing with boring tools, they should be made of wrought iron; and for bores of the diameter we have been describing, they should be from $\frac{1}{12}$ to $\frac{1}{8}$ of an inch in thickness, and should be made in such a manner as to offer the least possible resistance in being forced down the hole, or in drawing the tools up through them. They may be manufactured in lengths of 5 and 10 feet, one end being made to fit in a lower pipe, and the upper end to receive the lower extremity of the pipe to be joined to it. They must be connected together by small countersunk screws, so that they may easily be separated when they are drawn up, and so that the screws will not hook up in the side of the bore. The lower end of the first pipe should be toothed as in the annexed cut, and the teeth should be tempered, so that on being forced down, the teeth may cut away any asperities in the sides of the hole.

FIG. 36.



The interior diameter of the pipes must be sufficient for the tools to be worked up and down with ease, or we shall be deprived of those tools which will not pass down the piping; on the other hand, unless the whole be widened in diameter, we cannot pass down the pipes of which the exterior diameter is greater than that of the hole already bored. We may also, after piping down a certain distance, proceed through strata which do not require pipes, and again lower down we find them again requisite. Therefore, either we must use pipes of such a diameter that they will pass through the first, or we must employ tools which will bore, under the piping first let down, a hole of a diameter sufficient to allow these pipes to be driven further down.

The tools employed for widening a bore hole are very various; but it will be found that a stout auger of sufficient diameter will make its way very quickly through almost any earth, where an interior hole has already been bored; and where it is obstructed, a jumper of the description shown at Figs. 9, 10, 11, will drive in any obstruction; or one of the form shown in the annexed cuts, Figs. 37 and 38, will also work well, as it will act by being raised up and down, or by turning round. The projecting cylinder *a* acts as a guide. Tools of a more difficult con-

Fig. 37.

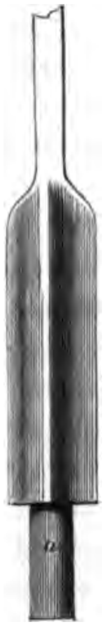


Fig. 39.

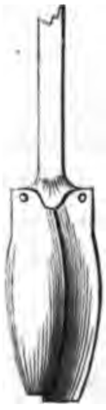
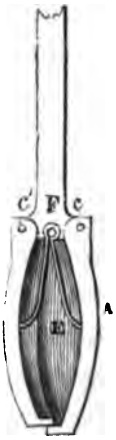


Fig. 41.



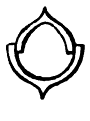


Fig. 40.

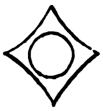


Fig. 38.

struction and use, are those which are required for boring under piping a hole of a diameter equal to the one of the exterior circumference of the pipe. We have seen many, and they are all complicated; the best that we are acquainted with is shown in Figs. 39, 40, and 41, being an elevation, plan, and section. In Fig. 41, A, A′ are two blades which pivot on the two axles, C, C′; these two blades are thrust out by the springs at E, which are fixed at, and work from the point F, which is an extension of the shank. These two blades overlap each other, and two plates at the lower extremity prevent the introduction of earth or stones. By removing one of the pins at C, C′, oil may be introduced, which keeps the whole in perfect working order, allows the instrument to be cleaned out, or the springs to be renewed when necessary. It is inserted into the piping, and descends by means of the lengthening rods; and on reaching the lower end of the pipes, the springs thrust the edges of the blades into the rock or earth to be cut away, and after proceeding any depth, it is taken out, and an auger introduced to clear out the material cut away; the form of the blades allows of the tool being drawn up through the pipes, the sides of which push back the springs. This tool works perfectly well, and does not easily get out of order. On reaching the bottom of the piping, the lower part comes in contact with the sides of the hole, and the head piece being turned round, the tool cuts away the sides of the hole. Any small quantity of material not bored out by the tool, may be cut away by means of the teeth of the pipes.

An accident of not unfrequent occurrence is the breaking off of one of the lengthening rods; this may occur either by its being snapped off, sometimes in two or three pieces, from allowing the tools to drop too suddenly down the bore, or from twisting against too powerful a resistance. A little caution, therefore, will prevent this, which is one of the most troublesome accidents which can occur in boring, from its often occupying several hours to extricate the tool; sometimes, indeed, this cannot be accomplished at all, without very great loss of time, and there is nothing left but to commence a fresh bore. Another serious accident which may happen, though less frequently, is when, in consequence of want of piping, the sides of the bore fall in and bury the tool at such a depth that it cannot be extricated; to these accidents we may add, that of a pipe being driven in by lateral pressure; this last being of a very serious nature, but of rare occurrence if the pipes are of good material and well put together.

Fig. 42.

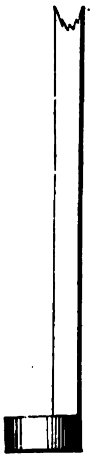


Fig. 44.

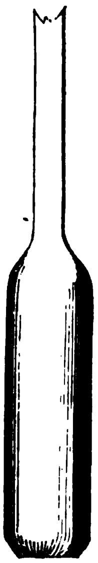
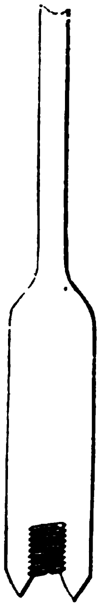


Fig. 45.



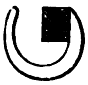


Fig. 43.

When the rods break from too powerful torsion, it is generally a little above or below one of the joints, and, when broken a little above, offers the most simple case for extraction; this is effected by the hook shown in Figs. 42 and 43, which is more easily done if the broken end of the rod does not adhere to the sides of the bore, but stands upright, or nearly so. The shank of the hook being screwed, the same as the other tools, to a length of rods, we must endeavour to bring the lost rod, below the joint, into the hook; and as we can correctly ascertain the depth at which this lies, from the upper broken length which is brought up, this is no very difficult matter to accomplish; and having once hooked it, twist it pretty tight, and gradually and steadily haul it up.

When the rod is broken off just below a joint, it is more difficult to seize it with the above hook. Another instrument is then made use of; see Figs. 44 and 45, the latter of which is a section of a hollow cylinder; the interior diameter is a little greater than that of the rods, and somewhat less than the diagonal of the square of the rod; this cylinder is funnel-shaped at the mouth, and the exterior end is slightly rounded off, that it may not catch in the sides of the bore; above the funnel mouth the hollow is strongly screw threaded, and it should be pretty highly tempered, that it may bite easily on the end of the broken rod. This instrument being fixed in the same manner as the foregoing one to a length of rods, it is let down the bore, the object being to get the broken end into the inverted cup, and by a few turns to screw it on, some pressure at the same time being used, but not sufficient to break the threads of the screw; when at a depth of 30 or 40 feet, the weight of the rods is alone sufficient, unless the broken rod and tool are found to turn in the bore, when greater pressure may be exerted.

When the materials have fallen in from the sides of the bore in such quantities that no proper effort can extricate the rod, we must introduce the hook (Fig. 34), and, seizing the rod as low as possible, unscrew those lengths which are not buried in the fall, and haul them up. We must next with an auger uncover another portion of the rod, and this must be carefully done, or this tool will be broken against the sides of the buried shank. Having cleared away sufficient material by these means, we must again use the hook to pull up the next length of rod, and by alternating these methods, extricate the whole before the work can be proceeded with.

We have already stated that the pipes must be in lengths of 5 and 10 feet, the ends to fit one to the other, and the lower end of the pipe first let down should be toothed and tempered for the purpose of cutting away any asperity or projection in the sides of the bore. Having sufficiently widened the hole for the *easy* insertion of the first length, we proceed to forcing it down, and the greatest attention must be given to this being done in a truly vertical direction; for if it be not perfectly so, the tools used in future proceedings will be obstructed by the sides of the pipes, which will be eventually cut through. The bore being of sufficient size, the first joint of pipe is pushed down until about 18 inches or 2 feet in length remain above the surface. The collar (Fig. 46) is then put on. The screw *b* being taken out, this collar opens by means of the hinge *c*, and being passed over the pipe,

FIG. 46.

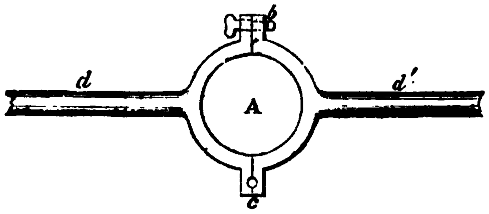
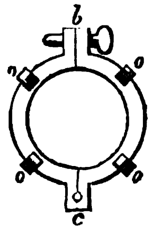


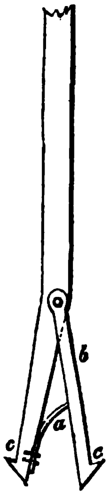
FIG. 47.



suspends it in the bore by the two arms *d, d′*, resting on the planking on the platform. Another collar, shown at Fig. 47, having in the mean time been fixed to the next length of pipe, perfectly at right angles to the axis of the pipe, which will not otherwise hang in a perpendicular direction, it is then suspended to the claw by pieces of chain passing through the eyes *o, o*. This collar is fixed and tightened to the pipe by the same means as in the preceding figure. The suspended pipe is then allowed to descend, and the lower extremity being inserted into the one in the bore at the end above ground, they are screwed together in the manner explained at p. 33. This being safely done, the next length is then allowed to drop down the bore by its own gravity, or it is forced down by the collar (Fig. 46), being raised higher up, and used in the same manner in which we work the head-piece. Or a few blows with a mace may be struck on the top of the pipe, a piece of plank having first been laid upon it to prevent the edges being forced in. This second length being driven down, the preceding operations must be repeated if a third length of pipe is required.

The extraction of pipes is generally most difficult and troublesome, and in some cases next to impossible. They may be extracted by fixing the collar tightly to the piping above the surface, passing the claw underneath it, and hauling them up by means of the rope. Or they may be pulled up by inserting through the pipe a tool, shown at Fig. 48, until it reaches the teeth, when the spring *a*, thrusting out the moveable arm *b*, the projecting parts, *c c*, hook under the pipe, and this tool, when thus situated, will often, by being pulled up, extricate the pipes. This tool is shown with the arms sprung out to their full opening.

Fig. 48.



We have already mentioned the bags for containing samples of the strata bored through, and can only add, that no borings should be taken without being provided with them. We remember a case when, the note book being lost or mislaid, the borings were plotted from the notes in these bags, and being afterwards compared with the memoranda in the book, which had been recovered, these plottings were found perfectly correct.

The note-book or register for inserting the required memoranda while the borings are being taken, will now be explained, and practical examples given. The number of the bore is first to be noted, the mileage and any memoranda which may serve to mark the spot, as near a house in the waste of a road side, by a tree, or near a hedge, &c.; next the depths from which the different earths and rocks are extracted, hard or soft, dry or fluid, and under the head of general notes may be inserted memoranda of time in cutting through rock, as although, from different tools being used, and these being besides unequally sharp at various times during the operations, it is not to be expected that the relative hardness of the materials can be ascertained; still the memoranda will lead to an approximation. At the end of the book, notes should be kept of the number of men employed, their wages, &c. With the boring apparatus we have described in the foregoing pages, four men will be found sufficient, besides the man in charge of the horse and cart.

The following is a form of register which may be always kept in readiness in a book reserved entirely for borings, and, if all the necessary observations are made in their proper columns, will often be of future service for reference, particularly if the maps, with the line laid down, be preserved.

Borings taken for the ——— Railway.

Date.	County. Parish. No. of Field. No. of Bore.	Mileage.	Depths.	Materials.	Remarks.
May, 1846.	.... Bore No. 1. In waste of road.	10 miles, 4 furlongs, 6 chains.	1 ft. 4 7·6 10 20	Gravel. Fine loamy gravel. Coarse gravel. Yellow clay. Middling gravel.	
	Bore No. 2. In waste of road.	10 miles, 5 furlongs, 4 chains.	5 7 10·6 19 24 39	Gravel. Silt. Fine close gravel. Fine sharp clean sand. Fine loamy gravel. Middling size, strong binding gravel.	

Date.	County. Parish. No. of Field. No. of Bore.	Mileage.	Depths.	Materials.	Remarks.
May, 1846.	Field 18. Bore No. 3.	10 miles, 6 furlongs, 5 chains.	4 ft.	Yellow clay.	
			12·6	Loam,	
			20	Sand, with a very little clay.	
			32·6	Fine gravel.	
			45	Loose coarse gravel.	
			70	Yellow marl.	
			84	Chalk.	
	Bore No. 4. In waste of road.	10 miles, 7 furlongs, 4 chains.	2	Soil.	
			10	Middling gravel, strong and loamy.	
			20	Yellow clay.	
			22·6	Coarse gravel.	
			24	Yellow clay.	
			30·9	Yellow marl.	
			64	Soft white chalk,	The chalk is lean, rather dry, a few flints, and pyrites.
	Bore No. 5. In waste of road.	11 miles, 1 furlong, 8 chains.	1	Soil.	Yellow clay is prominent throughout these beds.
			2·6	Middling gravel, very clayey.	
			4	Strong loamy, rather coarse gravel.	
			4·6	Coarse yellow clayey sand.	
			5	Coarse loam.	
	Field 27. Bore No. 6.	11 miles, 2 furlongs, 4½ chains.	1·6	Soil.	
			4	Gravel strong, rather coarse.	
			7	Loam.	
			18·6	Yellow clay, very wet.	
			42	Blue clay.	
	Field 29. Bore No. 7.	11 miles, 3 furlongs, 5 chains.	1	Soil.	
			3·6	Coarse loam.	
			5	Sand and water.	
			7	Yellow clay.	
			9	Middling gravel.	
			12	Coarse gravel, with large stones.	
			15	Loam.	
			22·6	Brownish clay.	
			48	Blue clay.	
	Bore No. 8. In waste of road.	11 miles, 4 furlongs, 6 chains.	0·9	Soil.	
			2	Loam.	
			4·6	Fine sand.	
			7	Gravel.	
			9·6	Yellow clay, very wet.	
			12	Blue clay.	
			27	White chalk.	

Date.	County. Parish. No. of Field. No. of Bore.	Mileage.	Depths.	Materials.	Remarks.
May, 1846.	Footpath 3. Bore No. 9.	11 miles, 5 furlongs, 7 chains.	1·6 ft.	Clayey soil.	
			3·6	Stiff loam.	
			5·9	Sand fine, with a little clay.	
			7	Small gravel.	
			13	Yellow clay.	
			23	Blue clay.	
	Bore No. 10. In waste of road.	11 miles, 6 furlongs, 7 chains.	3	Yellow clay.	
	Footpath 5. Bore No. 11.	12 miles, 2 furlongs, 7 chains.	0·9	Soil.	
			2	Loam.	
			3·6	Small clayey gravel.	
			5	Coarser gravel.	
			6·6	Loam.	
			7·9	Fine clayey sand.	
			10·0	White chalk.	
			10·6	Flints.	
			14	Chalk with a few flints.	
			14·6	Flints.	
			24	Chalk.	
	Field 34. Bore No. 12.	12 miles, 4 furlongs, 1 chain.	0·6	Soil.	
			2	Loam.	
			3	Fine clean sharp sand.	
			4·6	Yellow clay, a little sandy.	
			6	Loam.	
			9	Coarse gravel.	
			10	Chalk.	
			10·6	Chalk flints.	
			13	Chalk and pyrites.	
			14	Flints.	
			16	Chalk.	
			29	Grey chalk.	
	Bore No. 13. In waste of road.	12 miles, 4 furlongs. 1¾ chain.	0·9	Soil.	
			2·6	Fine gravel.	
			4	Coarse gravel.	
			5·6	Loam.	
			9	Gravel.	
			11	Coarse loam.	
			13·6	Sand, a little clayey.	
			15	Yellow clay.	
			17	Yellowish marl.	
			19·6	Chalk.	
			21	Chalk and flints.	
			24	Chalk.	
			25	Chalk and flints.	
			34	Chalk.	

The borings are plotted to a large scale and often perpendicularly to the vertical direction, for the convenience of space. A red line is drawn through the section where the bore has been taken, on which the depth is marked, and the number of the bore, that easy reference may be made to the plotted boring, which is numbered also.

We have already remarked that the person entrusted with a set of borings should take sketches and measurements of the various bridges and culverts over rivers, streams, and rivulets crossing the line, particularly the span and headway, as also of culverts or barrel drains under roads near the line. Besides these remarks, it is of importance that he should carefully observe the subsoils, wherever they are open to view, in the cuttings of roads and banks of streams, in or near projected cuttings on the line; careful observations should also be made in pits and quarries, where not only the nature and qualities of materials in the strata may be ascertained, but also their dip or slope; information may also be gleaned from pitmen or quarrymen. Where these observations are judiciously made, they are often of service, particularly when the roads, pits or quarries, &c., are across or close to the line.

Without attempting a geological or mineralogical treatise on the various rocks and earths of British strata, we will endeavour to give a short description of the various subsoils met with, as a slight guide to those who have not given any attention to the subject; and we strongly recommend the study of earths and rocks, wherever they are met with developed, and also of the natural slopes at which they stand—this being a subject of the greatest importance in all cuttings and embankments. By means of the alphabetical index, easy reference may be made when any information contained in these pages is required on any earth or rock.

Chalk, when pure, consists of lime and carbonic acid in nearly equal proportions, and is too well known to need description. In the geological formation of the earth, chalk occupies a very prominent feature, being extensively developed over Europe, and covering a very large tract in the south of England, from whence it runs to the north-east into Cambridgeshire, and to the north into Yorkshire, terminating at Flamborough; it also runs through Surrey and Kent, and through Sussex, Hampshire, and Dorsetshire, terminating at the coast. This stratum forming the upper portion of the secondary strata, is covered in many places by the tertiary deposits, as well as by the alluvial and diluvial, consisting mostly of sands, gravels, clays, loams, and marls. The chalk contains an immense variety of marine shells, and other remains. It is separated by a deposit of marl from the green sand, which is the next stratum of the secondary formation.

The chalk is divided into two formations, the upper and lower chalk; the upper is white, soft, and containing iron pyrites, flints, at irregular intervals, and in beds from 6 inches in depth to 2 and even 3 feet; these beds dip sometimes at a very considerable angle with the horizon.

The lower chalk is of a greyish appearance, sometimes dark grey, harder than the soft chalk, and seldom contains any flints.

The slopes for chalk cuttings are very uncertain. There are many chalk pits where the slopes stand quite, or very nearly vertical, but frost and heavy rains will occasionally bring down large masses; and even in slopes of ¾ to 1 the same thing occurs, and this appears more likely to happen in chalks of a loose friable nature. There appears little doubt that in the soft chalk, beds of flint, a little distance apart, assist in maintaining the slope; ½ to 1 may then be ventured on, if not of a very great depth, say under 50 feet. When more, ¾ to 1 and 1 to 1; chalk that is wet will require 1½ to 1; and the grey chalk in blocks will stand at ¾ to 1. In taking chalk borings it is of importance to ascertain whether the chalk is much shattered or sound, as it will be evident that if the latter there will be a greater probability of the slopes standing at a greater inclination than it would in loose blocks with unequal and uncertain bearings.

The basis of clay is alumine, and it is by mineralogists termed anhydrous silicate of alumina. The appearances of clay are very various, yellow, red, brownish, and blue, from the effect of iron; when brought up from any depth it is cold, wet, and tenacious. Clays when charged with little or no oxide of iron, burn of a good white colour; but in general they burn of a light or deep red, or yellowish red. For the purpose of testing, it is better to burn them very slowly, over or near a moderate fire, than to thrust them into an ardent one.

The Oxford—so termed from its occupying a considerable tract in the neighbourhood of Oxford—is of a greyish blue, and contains large beds of septaria.

The London clay is a large mass of a brownish or bluish clay, extending over Middlesex, Essex, Surrey, &c., and contains nodules of lumps of septaria; this clay when wetted is impervious to water.

Plastic clay—so termed from its use in making pottery—consists of beds of fine clay, sands variously coloured, and sometimes pebbles. The plastic clay is subjacent to the London clay, and overlies the chalk, forming an intermediate bed between these two strata; this clay contains a variety of fossil shells, and some beds of vegetable matter in a state resembling coal, termed lignite.

Clay ironstone is a brownish earthy-looking substance of very great weight, containing about 30 or 40 per cent. of iron: it is found in regular beds and in detached lumps, between, or in beds of highly indurated clay, often of many feet in thickness; this indurated clay is of a bluish or blackish colour, and is termed shale; it is found in the coal formation. The clay iron-stone is also found, and in great quantities, in deep beds of a softer clay.

Fire clay—so termed from its use in the manufacture of fire bricks in furnaces—is the produce of the indurated clay above mentioned.

In the "Wealden formation" of Kent and Sussex, in the "new red sandstone formation" of Worcestershire, Warwickshire, Staffordshire, Leicestershire, Shropshire, Nottinghamshire, Yorkshire, East Riding, a very red clay is found occasionally of a fine texture; this clay often contains calcareous matter, which gives it a greyish or light blue appearance, when it becomes a grey or bluish marl.

The yellow clay, so common almost everywhere, is found in the alluvial, diluvial, and tertiary deposits.

From the nature of clays, few questions offer more difficulties or uncertainties in determining slopes of cuttings and embankments. A lump of clay is very difficult to saturate with water, but once wetted is very retentive of moisture. If a moderately-sized piece of clay be placed in water, long before any portion of the centre is even damped, the outside will be found in a state of solution, and if it be placed on an incline it will immediately slip off. If therefore the upper portions of cuttings lie on a clay retentive of water, such as blue clay, or on shifting sands, a slip must ensue. Again, if in excavating, soaks are found, as the water oozes out it carries away portions of the cuttings; in this case the water must be drained off, a few stakes may be driven in, and binders put upon them. Another difficulty in clay cuttings and embankments is, that during summer heats clay cracks and opens, the subsequent rains percolate the fissures, the clay swells, bulges out, and often slips. There is no remedy for this but careful and extensive drainage. In clay cuttings and embankments, the greatest care must be taken to keep off all water, cracks and fissures must be carefully punned up, and six inches of soil laid on as quickly as possible. Where stone is in abundance, the Oxford clay and the London clay may be walled up; but unless there is besides efficient drainage, the walls will be thrust out by the swelling clay. Clay cuttings, under 40 feet deep, are *never* made less than 1½ horizontal to 1 vertical, which will give an angle 30° 42′; deeper than 40 feet, the slopes should be at 2 to 1 at least, and at times 3 to 1. In London clay or Oxford clay, it is very doubtful whether they will stand well even at this slope, and 3 to 1 is often given. In embankments, unless sufficient slope is at once given, continual slips will occur during consolidation, and even afterwards; it will appear inconsistent to add, that London clay, in considerable depth of cutting, has been known to stand at ½ to 1, the surface saturated by rains merely peeling off in wet weather; but the chance of clay standing at such slopes is too hazardous, and the danger too great to be tried.

Chert is a silicious substance, black and grey, occurring irregularly and in beds, in oolitic and magnesian strata, the same as flints occur in the chalk formation.

Gravel belongs to the alluvial, diluvial, and tertiary deposits, and is derived from scattered fragments of older rocks. It consists of silicious and calcareous stones mixed up with sand, clay, loam, and iron ores.

The nearer it resembles a pebbly beach, the cleaner it is termed; with a small quantity of sand, it is clean sandy gravel; with clay or loam, it is clayey or loamy gravel. It enters into the composition of concrete, and when of any depth affords a good subsoil for foundation, from the water freely percolating through it, without any risk of the soil slipping. Gravel stands well at 1½ to 1.

Granite, so termed from its granular appearance, in the most common acceptation of the word, is composed of quartz, felspar, and mica, intimately blended and compounded together; the felspar being the most abundant, and the mica the least. The felspar is often developed in large crystals, besides being mixed up with the quartz and mica as a matrix; it is then termed porphyritic granite, as also when the quartz is in large crystals, which is, however, more rarely. Schorl sometimes assumes a feature in some granites, when it may be termed schorlaceous granite. In talcose granites, talc usurps the place of mica. Hornblende is also a characteristic mineral in some granites.

We have two very distinct granites—the Cornish and the Scotch or Aberdeen. In the granite of Cornwall the felspar is abundant, and often appears in large crystals, and schorl is also a characteristic in this district. When schorl is exchanged for mica, or is only blended with quartz, the rock thus constituted is termed schorl rock. The China stone or China clay used in potteries, is a kind of protogine, in which talc takes the place of mica; the quartz, felspar, and talc in this rock are in various proportions; it has been much used in ancient buildings in that part of the country. This granite is sometimes very quartzose; and occasionally the quartz disappears altogether. The talcose granite cleaves well, and is a good building stone. The granite of Cornwall appears, however, more generally in coarse-grained masses, coloured of a yellowish and reddish hue by the felspar; whilst the Scotch, commonly termed Aberdeen, is finer grained and of a greyer tint.

A marked distinction between the Scotch granite and the Cornish is, that hornblende, instead of schorl, appears in the Scotch kind, and it also often usurps the place of mica. The quartz sometimes disappears in these rocks, leaving only the felspar combined with hornblende, which latter is to be found in large crystals, and the felspar is commonly white; occasionally this last mineral disappears, leaving the hornblende by itself in a granular mass, which is generally known as basalt. The same granite as the Cornish, consisting of quartz, reddish felspar, and mica, occurs pretty commonly in Scotland, but there is a greater quantity of grey granite, which is finer grained and of more regular construction.

Along the coast of Ireland, from the Bay of Dublin to 20 miles north of Waterford, is a very fine tract of a remarkably beautiful granite, being very pure from other ingredients than the felspar, the quartz, and the mica; the first being of pure white or slightly yellow or grey, the quartz grey, and the mica of a greyish white; it is sometimes fine-grained and compact, and at others of a coarser description. The weight of a cubic foot of granite is about 187 lbs.

Granite contains the ores of many metals, among which are tin and copper in large quantities; but tin is the metal most usually found either in veins or spread throughout the mass of rock.

Gneiss is formed of the same minerals as granite, of which gneiss is an accumulation of fragments broken up, stratified, and laminated, instead of being in granulated structure: it contains beds of mica, slate, limestone, talc, schist, serpentine, and quartz.

The greywacke rocks occupy considerable portions of Cornwall and Devonshire; they occur in the neighbourhood of the lakes in Westmoreland and Cumberland, and form large portions of the mountainous district of South and North Wales; among these rocks are situated some of the rich copper, tin, and lead mines of Cornwall and Devon, as also the lead mines of Wales. These rocks are of an indefinite description, consisting of sandstones often fine-grained and slaty, and sometimes conglomerates of rocky slates, among which are roofing slates, and of limestones in beds; they often also contain greenstone. The upper portion of this series is occupied by the sandstones and conglomerates, and the fine-grained, slaty, and altered rocks form the lower portion, insensibly passing into

Clay slate, which lies in beds of various magnitude; it is of a grey or blackish colour, and often contains mica, quartz, and felspar, in small grains. The clay slate and the greywacke rocks cleave easily; the latter are of greyish blue generally, but sometimes of a brownish red.

Magnesian limestone is a geological term applied to a stratum subjacent to the new red sandstone, and, as the name implies, derived from magnesia, which is found in it in the proportion of about 20 per cent. This limestone is of a compact granular texture, and of a whitish, yellowish, or slightly brownish colour. From this formation is quarried at Mansfield Woodhouse, in Derbyshire, the stone termed Bolsover, of which the new palace at Westminster is being erected, where its appearance already speaks in a language not to be controverted: a foot cube weighs 151 lbs. This formation also yields a magnesio-calciferous limestone of a valuable kind. This rock does not occupy a very extensive tract in this country; the principal stratum stretches from Nottingham to Durham. The thickness appears to be from 250 to 300 feet. Mines of lead and zinc are worked in some parts of it. York Minster, Selby Cathedral, Westminster Hall, Ripon Minster, St. Mary's Church, and the Minster, Beverley, are constructed with this stone, as well as numerous ancient halls, and a great number of modern buildings in London, and in various parts of England.

Limestone, in its purest state, is composed of lime and carbonic acid, when it is termed statuary marble; its pure white saccaroidal appearance is too well known to need description; with this we have little to do, but much with the limestones in which clay and sand enter into composition. The following observations on limestones, as also those on sandstones, are selected from the Report of the Commissioners on different quarries in England and Scotland, which we consider will be the more valuable to the engineering student from their affording information in many different parts of the country. These notes will contain the names of the quarry, the component parts and colour; weight of a cubic foot in ordinary state, the depth which may be quarried, as also the size of the blocks. We will begin with the Portland as one of the most valuable which this country produces.

The decomposition of limestones, which are composed of carbonate of lime or carbonates of lime and magnesia, relatively to their own kinds, depends on the mechanical aggregation of the parts; those stones which are of the most crystalline construction being the most durable.

Portland stone belongs to the oolitic* formation.

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* The oolitic formation consists of the following three strata three times repeated; first a limestone, composed of small oviform particles cemented together by a calcareous and often argillaceous cement; this first bed rests upon one of an argillaceous sand and sandstone, which reposes on a thick deposit of clay. These strata extend from Dorsetshire to Yorkshire, upon a breadth of 20 and 40 miles, and are 2000 feet in thickness. The middle oolite rests upon the lower, and the lower oolite rests upon the Oxford clay, which, indeed, is the basis of the whole oolitic system. The oolite resting on Oxford clay appears to yield a very indifferent stone.

Nature scarcely yields a more beautiful material than some of the sands, varying in different strata through blue, red, and yellow, in every graduated tint; it is formed of the disintegration and breaking up of silicious stones, and when perfectly clean, or free from other matter, is sharp to the touch, and leaves no stain, and, if cast into a vessel of pure water, will sink without troubling its transparency; but ferruginous sand will stain, and clayey sand will have a rather unctuous touch, and will stain also. Fossils have been deposited in vast beds by the secondary revolutions of the earth, whilst the sands termed virgin remain in their natural site. Both pit and river sands are used as ingredients to mortar; if pit sands, the white is the worst. Whichever is used, it should be sharp, and free from earth or dirt.

Sand is an excellent material for embankment, both on account of the facility with which it may be teamed, as also from its consolidating very rapidly. Sand seldom occurs in very deep beds, but usually with other alluvial and diluvial soils. With gravel it stands perfectly at 1¼ to 1. These observations refer to sand in the above-mentioned deposits; for where sand is found in indurated masses, as in the new red sandstone and old red sandstone formations, it will stand perpendicular, as may be observed in the deep cuttings of the Liverpool and Manchester Railway, near Liverpool, and along our cliffs.

Sandstone consists of silicious particles united together by an argillaceous, calcareous, or silicious cement, and as often of large and small grains of quartz, decomposed felspar, and often mica cemented in the same way; when the latter enters into combination, the stone is more than usually laminated, from the mica being deposited in layers parallel to the beds.

The ferruginous sandstone, so common in England, is a very indifferent building material, as ancient edifices constructed of this material plainly show by their decomposition; and it is to be regretted that the same defect of material is already visible in some of the handsome modern buildings of Liverpool.

The sandstone of Derbyshire consists mostly of moderate-sized quartz grains and decomposed felspar, and often a little mica, united by an argillo-silicious cement, generally of a brown, red, yellow, or grey colour, in spots or stripes.

Dumbartonshire. The sandstone in the President quarry consists of fine silicious grains, united by an argillo-silicious cement; micaceous; pale brownish grey.

The sandstone in the county of Durham is very similar to that of Derbyshire.

Edinburghshire. The sandstone from Cragleith quarry; fine silicious grains, with an argillo-silicious cement; slightly calcareous; a few plates of mica; weight of cubic foot 145 lbs. 14 oz.; vary from 3 inches to 3 feet of bed rock, with occasional layers of liver rock; they vary from 6 inches to 12 feet; blocks of any practicable length and depth, varying in depth from 6 inches to 10 feet.

Gloucestershire. The sandstone from Viney Hill quarry, Forest of Dean, is a fine silicious sandstone, argillo-silicious cement, micaceous in plain beds: light purple grey; 156 lbs.; the regular beds consist of a silvery grey rock 12 feet deep; the latter very hard, and divided into several beds, the thickest being 4 feet; the red beds rather shaky, the thickest 3 feet; the silvery grey is finely laminated, and only fit for landings.

Kent. The sandstone of Calverley quarry, Kent, is of fine silicious grains, with a slightly calcareous cement; variegated browns; weight of cubic foot 118 lbs.; depth from 5 feet to 6 feet 6 inches; 3 beds, upper 2 feet, middle 3 to 3½ feet, lower from 9 to 14 inches; the upper bed is the softest; blocks from 70 and 80 feet to 500 feet.

Lanarkshire. The sandstone from Giffneugh quarry consists of fine quartz grains, with a calcareo-silicious cement, and is of a pale grey in the lower rock, and yellowish the 20 feet of upper, which is inferior to the lower, this being about 20 feet of compact stone, in beds from 1 foot to 8 feet deep. It is much used in Glasgow, the Highlands, and in Ireland.

Linlithgowshire. The sandstone from the Binnie quarry, near Uphall, shows a fine quartz grain, in an argillo-silicious cement, and weighing 140 lbs. per cube foot; it is of a brownish grey.

Monmouthshire. The sandstone of Abercarne and Newbridge is of a dark bluish grey colour, and consists of quartz and silicious grains, united by an argillo-silicious cement; weight of cubic foot 168 lbs.; in blocks from 1 to 10 tons. The docks at Newport and Cardiff are constructed with this stone.

Nottinghamshire. We have already spoken of the magnesio-calcareous sandstone with silicious grains, of Lindley's red quarry, near Mansfield; it is of a roseate brown, and weighs 149 lbs. per cubic foot.

Lindley's White quarry yields a whitish brown magnesio-calcareous sandstone, in beds from 6 inches to 4 feet 6 inches deep, and blocks of 10 tons.

Northumberland. The sandstone in this county is pretty similar to that of Durham, but of a superior quality.*

Perthshire. The sandstone from Mylnefield or Ringoodie is composed of fine silicious grains, with a calcareo-argillo-silicious cement, and is of a purplish grey; weight of cubic foot 160 lbs.

The sandstones of Ross-shire and Flintshire are very similar to those already mentioned, merely variegating a little in colour as the sandstones do in quarries at a short distance from each other, and often even in the same quarry.

The Shropshire sandstone is calcareo-ferruginous, grinding red, weight 146 lbs. per cubic foot; building grey 141 lbs. per cubic foot; blocks of 10 feet to 60 or 70 feet.

The Staffordshire sandstone may be had in blocks of very large size; it consists of quartzose grains, embedded in a calcareo-argillo-silicious cement. Many public and private buildings in Staffordshire are built with this stone; price from *7d.* to *1s.* per foot for selected blocks at quarry.

The Wiltshire calciferous sandstone is a good building material; blocks of 3 and 5 tons may be had; weight 153 lbs. per cubic foot; depth of beds from 1 to 3 feet. Used in Salisbury Cathedral and Wilton Abbey.

Yorkshire offers a great number of quarries well stocked with sandstones, from 2 and 3 inches to 5 and 6 feet in depth; it is brown, grey brown, cream-coloured, and nearly white; it is most generally of silicious or quartzose grains, in an argillo-silicious cement. Among others, the Whitby Company has some fine quarries. The Yorkshire sandstone quarries have supplied materials for the ancient and modern erection of many fine buildings and bridges, as Whitby Abbey, Sheerness, and Saint Catherine's Docks, Richmond and Caterick bridges over the Swale, Purse Bridge over the Tees, piers of chain bridge at Stockton, Scarborough and Bridlington piers, New Library and New University of Cambridge, Catholic chapels, Leeds, various public buildings in Manchester, Hungerford Market market-house, in very numerous castles, halls, public and private buildings, and on the London and Croydon, London and Birmingham, and other railways.

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* This county also contains much valuable limestone belonging to the "mountain limestone."

Alluvial is a geological term, applied to the results of changes in the earth's surface, due to causes within the existing period; changes which should be of deep interest to the engineering student, for in these changes he may study the operations of nature, in filling up harbours and estuaries, in throwing bars across the mouths of rivers, and sandbanks obstructing navigation, in forming deltas and raised beaches, rich alluvial beds deposited along the shores, in drifting sands, and undermining of cliffs.

Diluvial is a term applied in distinction to alluvial; diluvial deposits are not the result of existing changes, but are due to the last great catastrophes of the globe, and were produced by the partial breaking up of the older rocks. The agency of powerful torrents is undoubted, in having carried large boulders of rock to an immense distance from their original site, and in having deposited some of them, with smaller fragments, generally in valleys and on plains, though often also on summits of hills. The gravel beds and fragments of rocks scattered over different parts of England are examples of diluvial deposits.

Felspar is a hard, transparent rock; red, grey, green, and white. It enters into the composition of granite and many sandstones.

Flagstone is a sandstone divided into thicker or thinner beds by thin layers of mica: Yorkshire.

Gypsum is a combination of sulphuric acid and a calcareous earth; deprived by heat of its water of crystallization, it forms plaster. Gypsum often contains a considerable portion of carbonate of lime; the white or yellow, semi-transparent, and capable of polish, is termed alabaster; calcined, it is used in some cements.

Hornblende, a black lustrous mineral, entering into the composition of some granites.

Lias; this rock forms the basis of the oolitic system; the upper portion consists of a bluish clay, containing irregular and thin beds of an impure limestone, which has been termed *septaria*, and is employed in the manufacture of Parker's water cement; the middle portion is a blue marlstone, whilst the lower is termed the lower lias shale; this stratum throughout is divided by argillaceous partings, which decrease in number from the upper beds to the lower, and in the lower disappear altogether: in the different beds it is grey, blue, and white. This formation supplies in abundance a limestone of a blue colour, from the iron contained in it, from which a strong hydraulic lime is manufactured. Aberthaw, in Glamorganshire, is celebrated for its hydraulic limestone. The lias contains an immense quantity of marine fossil shells, remains of saurians, and beds of lignite.

Loam, a mixture of sand and clay.

Marl, a combination of lime or chalk, and clay; red, blue, grey, and yellow; it is abundantly found in the greater number of our stratified formations above the coal. Marl is rough and dry to the touch, and effervesces with acids; it is calcareous or argillaceous, according to the preponderance of lime or clay. It often consists of a mixture of broken shells and clay, when it is called *shelly* marl.

Millstone grit is a coarse sandstone, consisting of fragments of granite, in small rounded pebbles in all sizes, under a hen's egg, held together by an argillaceous cement; its usual appearance is that of a coarse conglomerate, but some of the beds have a fine texture; it affords an excellent material for millstones, whence it derives its name. Millstone grit occurs between the coal measures and the shale resting on the mountain limestone.

Peat, or moss, consists of decayed vegetable matter, plants and trunks of trees, buried in mud and silt, and occupies large tracts in many parts of England and Ireland, and is often of immense depth. A heavy embankment, seated on moss, is a most expensive work. George Stephenson crossed the Chatmoss by laying down a platform upon the moss, and by forming the embankment with the moss itself dried, in which state it was much lighter than the substratum under it.

Peat is often found under a bed of gravel, and on a substratum of clay or marl.

The Purbeck strata form the basis of the formation termed Wealden, in the secondary strata. They consist of beds of clay, marl, sandy and shelly limestones; the latter are formed by a mass of small shells, united by a calcareo-silicious cement; Purbeck may be advantageously used for steps and landings, having a firm compact texture, but, being capable of polish, is rather slippery.

Schist, a German word for slate, is applicable to all rocks which are apt to divide into thin plates, as micaceous schist, or mica slate, argillaceous schist, or common slate.

Schorl is a mineral of a deep black, opaque, and found in masses and crystallized; fusible into black glass; it enters into the composition of some granites, gneiss, and similar rocks.

Serpentine is a silicate of magnesia, distinguishable by its softness, smoothness, and bright mottled colours, and of a rather soapy touch.

Septaria is a term applied to beds and irregular lumps of impure limestone found in the Oxford and London clays, and in the lias. It is very hard, and enters into the composition of Parker's water cement.

Talc is a white, green, or yellow substance, soft and unctuous to the touch, leaving a white, pearly, lustrous trace on anything on which it is rubbed; it is lamellular, and may be easily divided into thin plates; it is lustrous and translucent; yields easily to the nail, and may be with difficulty fused into a white enamel. The massive varieties are granular and earthy.

The above characters distinguish it from chlorite, which is also green, but oftener dark green and sometimes black; fracture earthy, but somewhat scaly, and fusible into a dull compact slag, when it becomes magnetic.

CHAPTER III.

WORKING SECTION—SETTING OUT SLOPES—PREPARING LAND PLANS.

HAVING stumped and nicked out the straight lines and curves, it becomes necessary to prepare for taking the levels for the working section and setting out the slopes.

At convenient points, near the commencement of each excavation and embankment, and near the site of bridges, viaducts, tunnels, culverts, and all works, permanent posts must be fixed; these posts must be 4 feet long by 4″½ × by 4″¼, and must be sawn square at the ends and sides, and as the permanent posts are for reference to levels at future periods when the stumps have been removed, care must be taken that they be driven in such situations and in such manner that they will not be disturbed, and they must not be fixed in wet situations; these permanent posts must be hooped round the top with a strong iron hoop, and they must also have an inch plate on the top, for the levelling staff to stand upon.

The greatest accuracy is required in taking the levels for the working section, as any error committed will be carried into the works. The staff must be held on each centre stump, every one of these being flush with the surface of the ground; and in case of irregularity in this surface, then must the levelling staff be held between the stumps to get the levels of these irregularities. In crossing roads, care must be taken to get the level of the centre of the road and of the sides, as also the levels of the footpaths. As we come to the permanent posts, the levels must be tied into these, as so many B.M s.

In very sidelying ground, cross sections must be taken to facilitate the correct calculation of earthwork of excavations and embankments, for which purpose these cross sections should be plotted to a natural scale of 30 or 40 feet to 1 inch, and not less.

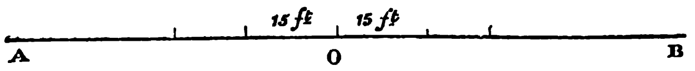
Where the level of any road crossed is to be altered, or the line of road in any way interfered with, a longitudinal section along the road, and cross sections to it, should be prepared, and also a survey, and the whole should be plotted to a natural scale of 40 or 50 feet to the inch.

The working section must be plotted to a scale of 3 or 4 chains horizontal, and 30 or 20 feet vertical to 1 inch; and the level of the rails being fixed, the heights at each chain must be calculated from the datum line to the formation line, which averages 2 feet below the rails, and the depth of cutting or embankment to or from the formation level must be also marked. The lengths and the rates of inclination of the rails, and of the slopes, the radius of curves, and the direction of curves, must all be marked on the section, as also the position of bridges and culverts when decided upon.

Setting out slopes is a term applied to setting out on the ground, on each side of the centre line of the railway, the width required for the base of slopes of a given vertical height and inclination, plus the width of half the road, to which is afterwards added a space of 8 or 10 feet for the breadth of ditch and cop, as the case may require. There are four distinct cases to be attended to in what is termed setting out slopes, viz., when the railway runs along the level of the surface of the country, in a cutting, or an embankment, where the surface of the ground is level across the railway; when the ground is sidelong, that is, when it dips on one side or the other of the railway, either over a cutting or on the seat of an embankment, a different mode of calculation is also required; when on sidelong ground a cutting occurs on one side and an embankment on the other side of the railway; these different cases will be treated seriatim.

When the railway to be constructed is to run along the level of the country, the matter is very simple, as we have then but to set out at right angles to the centre line half the width of the road, say 15 feet,

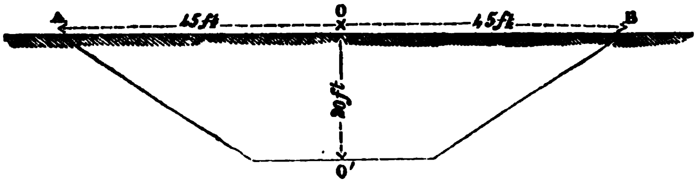
Fig. 1.



plus 8 or 10 for ditch and cop, when the thing is done as in Fig. 1; O representing centre stake, and A B the surface.

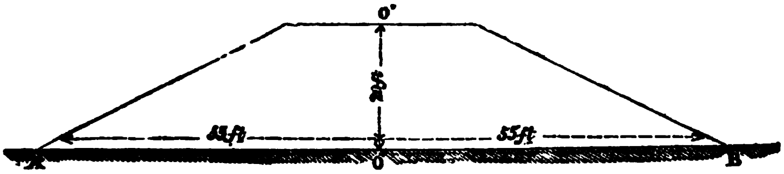
When in a cutting or an embankment, the surface of the land across the railway is level, or parallel with the horizon, is the next most simple case that offers. We have then only to add half the width of way, to the vertical height of the cutting or embankment, multiplied by the ratio of base of slope to height, as 1½ to 1 in cutting, 2 to 1 in embankment, as will be explained by means of the following cuts.

FIG. 2.



In Fig. 2, O is a centre peg, and at this point on the working section the vertical height, from the surface to the formation line, is 20 feet, and the cross surface of the country is level, then on each side we have but to set out on each side of the centre stake the half width of way = 15 feet, + 20 feet × 1½ = 30, and 15 + 30 = 45; these 45 feet set out at *right angles* to the centre line, determine the edge of the slope as at A, B. Fig. 3 shows the same thing done in embankment,

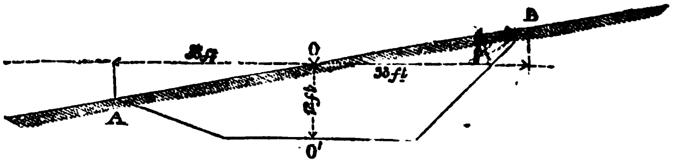
FIG. 3.



but the slopes are 2 to 1; thus, the depth of embankment being 20 feet, as in the preceding case, 15 feet being equal to the half way at the formation line is added to 20 × 2 (the ratio of inclination) = 40 + 15 = 55.

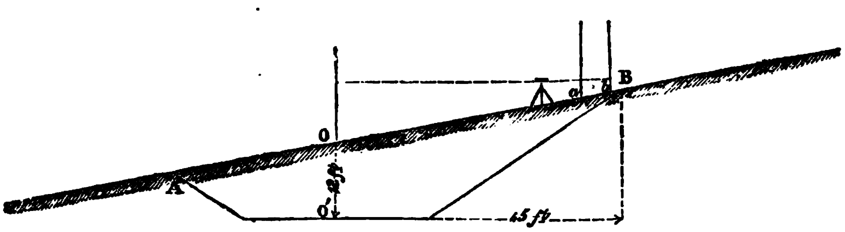
Nothing, however, could be more erroneous than this method of setting out slopes in cuttings or embankments on sidelong ground, as the Fig. 4 will show, for slopes set out on each side of the centre peg for a vertical height of 12 feet from the surface to the formation line;

FIG. 4.



for 15 + (12 × 1½ = 18) = 33 on each side, when we see that we have a great deal too much on one side and too little on the other. And this is evidently because the ground rises towards B and falls towards A. Let us therefore find the difference of levels between O and B, and between O and A. The usual method of proceeding is as follows:—to half the width way, say 15 feet, add the vertical height, say as in Fig. 5, 12 feet × 1½ ratio of inclination, or 15 + 18 = 33; on the

FIG. 5.

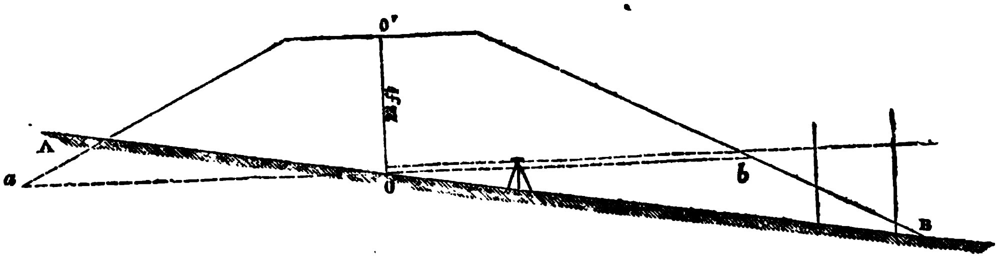


rising side of the ground set off this distance and somewhat more, according as the ground rises more or less, and find the difference of level between this *assumed* point and the level peg, by the centre stake; multiply this difference of level by the ratio of the slope, and add the result to the first computed distance, which will give us a much nearer approximation to the point desired. Now set up the staff at this new point, and again find the difference of level between this point and the level peg, multiply this difference by the ratio of the slopes as before, and again add the result to the computed half width; for all practical purposes this second result will be found near enough the truth most generally, but much depends on the practised eye in setting the staff at first near the desired point. For instance, half the computed distance being 33, add 6, = 39 feet, and let a staff be held at 39 feet from the centre line, and another staff at the level peg O; the difference of readings is 7·00 multiplied by 1½, the ratio of slope, gives 10·50 + 33 = 43·50, or 43½; let the staff *a* be then held at 43½ feet from the centre line or at *b*; the difference of readings is 8·00 × 1½ = 12 + 33 = 45; Fig. 5 shows how near this is to the desired point.

On the side of the ground which dips or falls, we proceed in a somewhat similar manner, but instead of setting up the staff beyond the computed half distance, it is to be set up rather nearer the centre line, and having ascertained the difference, and having multiplied this difference by the ratio of inclination, we *deduct* the result *from* the computed half width, instead of adding it, as in the preceding case, and set up the staff at the new point of approximation, thus found by subtraction; read off the difference of levels, again multiply the difference by the ratio of slopes, deduct again from the computed half width, and we shall again have a point near enough for all practical purposes.

In setting out slopes on the seats of embankments, the foregoing calculations are reversed, as Fig. 6 will show, as it is on the side of the fall that we shall have the greater width of base, and on the side of the rise the least. The dotted line *a* O *b* shows the width which would be required, if the cross section gave a level. In setting out slopes for embankments on sidelong ground, on the side of fall we *add* the result of the multiplication of differences of level by the ratio of the slopes to the computed half width, instead of deducting them in cutting. On the side of rise in this case we *deduct* this result of the multiplication of differences of level by the ratio of the slopes from the computed half width, instead of adding it. In the case of embankment at Fig. 6,

FIG. 6.



OO′ = 22 ft. is the vertical height, which, multiplied by 2, the ratio of inclination for the embankment, gives 44 feet, which added to 15 feet, the half breadth of way, gives 59 for the half computed width; a staff being set up at this distance, and at O, the difference of levels is 11 feet; this multiplied by 2 is equal to 22; 22 + 59 = 81; the staff being set up at this new point of approximation, the difference of readings is 13 × 2 = 26 + 59 = 85, which gives the edge of slope. In setting out the slope on the side of rise in this case, it must be remembered that the difference of level, multiplied by ratio of slope, is a negative quantity, and to be deducted from the computed half width.

The last case for our consideration is, when the line, being on or near the surface, and on sidelong ground, we have a cutting on one side, and an embankment on the other. Here we have no vertical height to multiply by the ratio of inclination; but we can at once see, on inspection of the ground, that a considerable width will be required for the base of slopes; on both sides the staff is held up beyond the 15 feet of half way, and for both sides the result of the multiplication is a positive quantity. The difference of levels at O and *a* is = 3·50 × 1½ = 5·25, and this distance measured off gives the required edge of slope. It will here be seen, that for short distances, as in the present case, one set of levels is sufficient. Fig. 8 is a case which will be

Fig. 7.

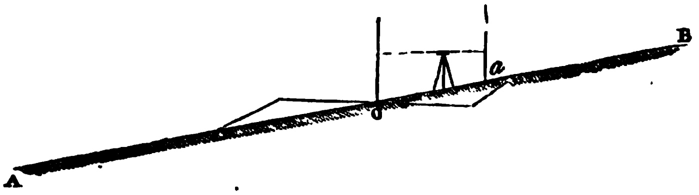
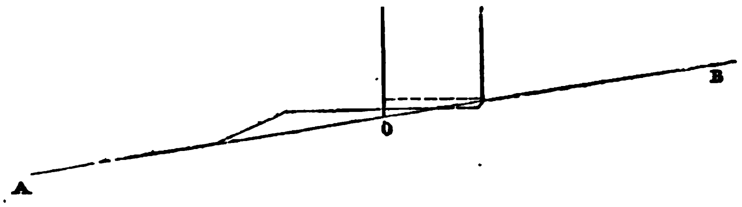


Fig. 8.



explained in describing the method of keeping the field book for this purpose, and making the calculations for the bases of slopes as we proceed with the work.

In this register the first column of numbers, is that of the chain stake or level peg, and the second, the vertical height of cutting or embankment, and the third gives the computed half width for the first point of approximation. Columns 4, 5, 6, the readings on the levelling staves, and columns 7 and 8, show the difference of levels between the centre pegs and the points of approximation; columns 9 and 10 are for these differences multiplied by the ratio of inclination of the slopes, and these added or deducted from the computed half width give columns 11 and 12 for the required half width for edge of cutting or foot of embankment. The signs plus and minus should be used to show whether the centre peg is above or below the surface on the sides of the half width. At stake 86, Fig. 8, we have an embankment of 2 feet, difference between centre stake and point of approximation = 2·20; but the embankment is raised 2 feet above centre stake, and 2 from 2·20 gives 0·20 to be multiplied by 1¼ for finding edge of cutting at this point.

Form of Field Book for Setting out Slopes.

Number of Level Peg.	Depth of Cutting or Embankt.	Computed half width.	Cross Section or Level Readings at right angles to Centre Line.			Difference of Level × or —		Difference of Level × by ratio of Slope, × or —		Required half width for edge of Cutting or foot of Embankment.	
			South.	Centre.	North.	South.	North.	South.	North.	South.	North.
Level. 20	- -	15·10	- -	- -	- -	- -	- -	- -	- -	15·00	15·00
Cutting. 31	20·00	45·00	- -	- -	- -	- -	- -	- -	- -	45·00	45·00
Embankment. 43	20·00	55·00	- -	- -	- -	- -	- -	- -	- -	55·00	55·00
Cutting. 65	12·00	33·00	15·00	10·00	2·00	—5·00	+ 8·00	—7·50	+ 12	25·50	45·00
Embankment. 78	22·00	59·00	- - 1·50	1·00 9·00	14·00 - -	- - + 7·50	—13·00 - -	- - + 15·00	—26·00 - -	44·00	85·00
On Level. 83	0·00	15·00	12·50	7·00	3·50	—5·50	+ 3·50	—11·00	+ 5·25	26·00	20·25
Embankment. 86	2·00	15·00	7·50	3·00	0·80	—14·50	{ + 2·20 } { + ·20 }	+ 9·00	+ 0·30	24·00	15·30

The ratio of inclination having been determined on, and the widths of slopes calculated and set out, these widths are marked off on the general plan on each side of the centre line, and the "*land plans*" are made to show the quantities or acreage required from each property; and this being ascertained throughout the line, these quantities per mile are tabulated on the plans as shown at Pl. III; three or four tracings of each property are then made, with the lands required shown, as also the quantities which will be wanted, and one of these is entered in the land quantity book for any future reference; the quantities per mile may be checked by computing these from the section quite independent of the plan. Previous, however, to marking off these quantities with this degree of accuracy, as also the approaches for bridges, it is often customary to set out on the plans certain widths of land on each side of the centre line; this is done without reference to sideling ground, and as if the surface of the country across the line were perfectly horizontal; a certain ratio of inclination for the bases of slopes being given, as 1 to 1, or 1¼ to 1, in cuttings, and 2 to 1 in embankment, the widths required are marked off from the vertical heights on the section, with a width of about 12 feet added for breadth of ditch. These quantities per mile are also checked by computing from the section; an approximation only is obtained in doing this, but it is sufficiently near to commence negotiations with the landowners.

It has already been observed that cross sections should be taken at every chain stump. The excavation or embankment at each chain is drawn on these, and therefore the width of land required on each side of the centre line. By employing both of these means together, they will be a check on each other, not only as regards quantities of land, but the more important consideration of width of slope, for if the proportions of horizontal to vertical determined upon be not correctly set out, there will be windings in the slopes most injurious to the stability of all earthworks.

Considerable care is required in drawing in the depths and widths of cuttings and embankments, on these cross sections, as also in scaling off the half widths therefrom.

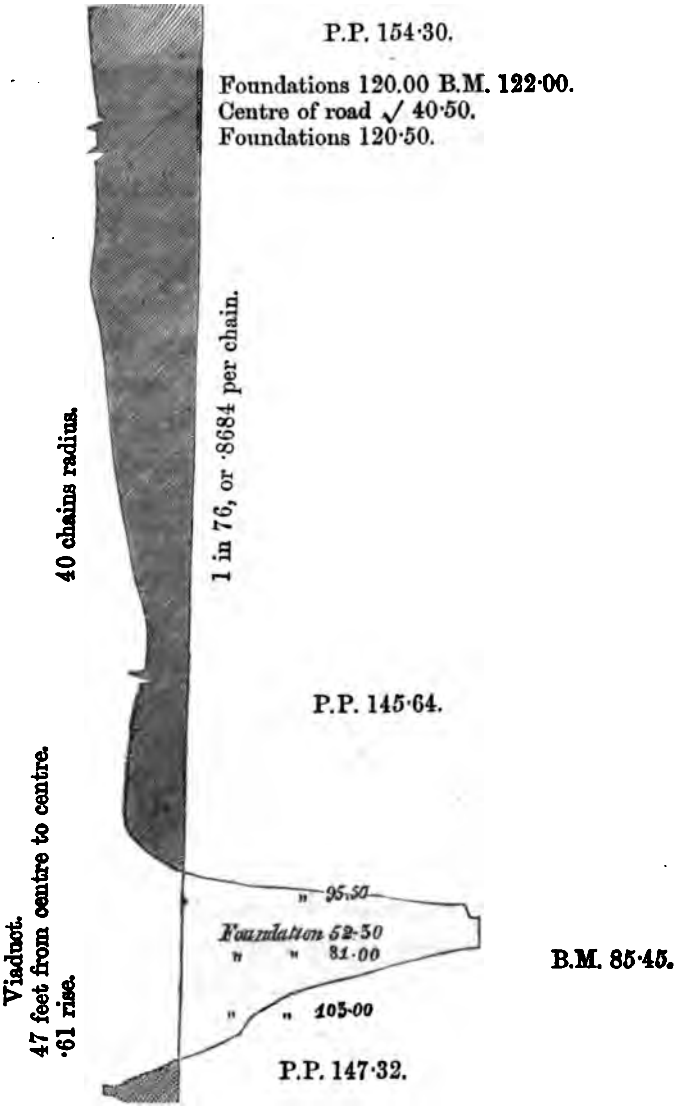
Equal care is also required in marking off, on each cross section, the chainage to which it refers on the ground.

The two systems of setting, either by cross sections, or by the method mentioned at the beginning of this chapter, are followed with equal success in setting out slopes, though perhaps, from habit, I am disposed to prefer the method first given. In both cases a cross staff is requisite.

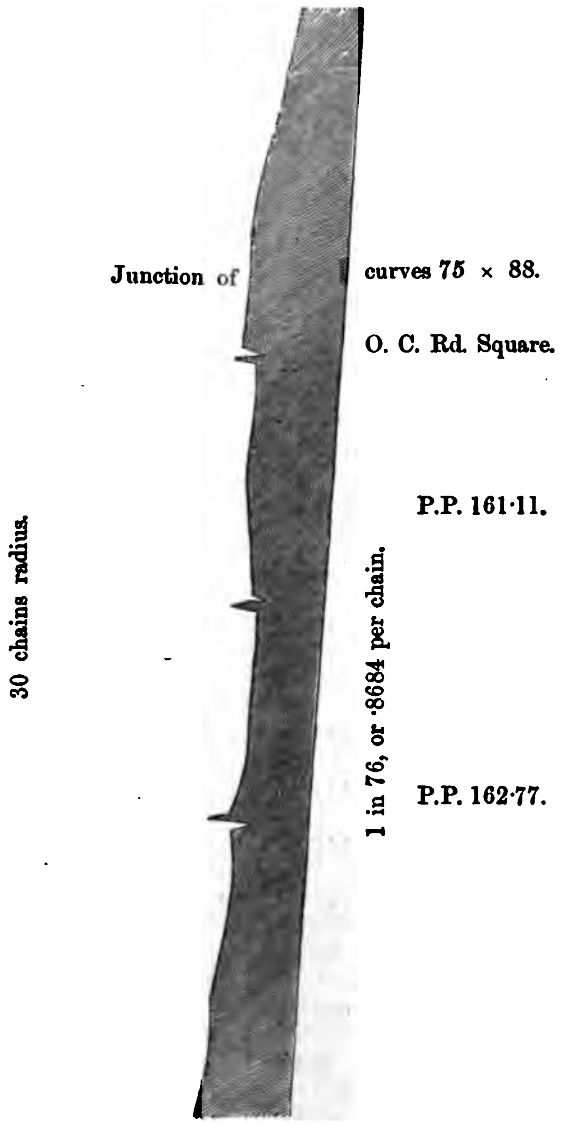
CHAPTER IV.

POCKET SECTION—SETTING OUT LEVELS OF CUTTINGS AND EMBANKMENTS, BRIDGES, VIADUCTS, ETC.

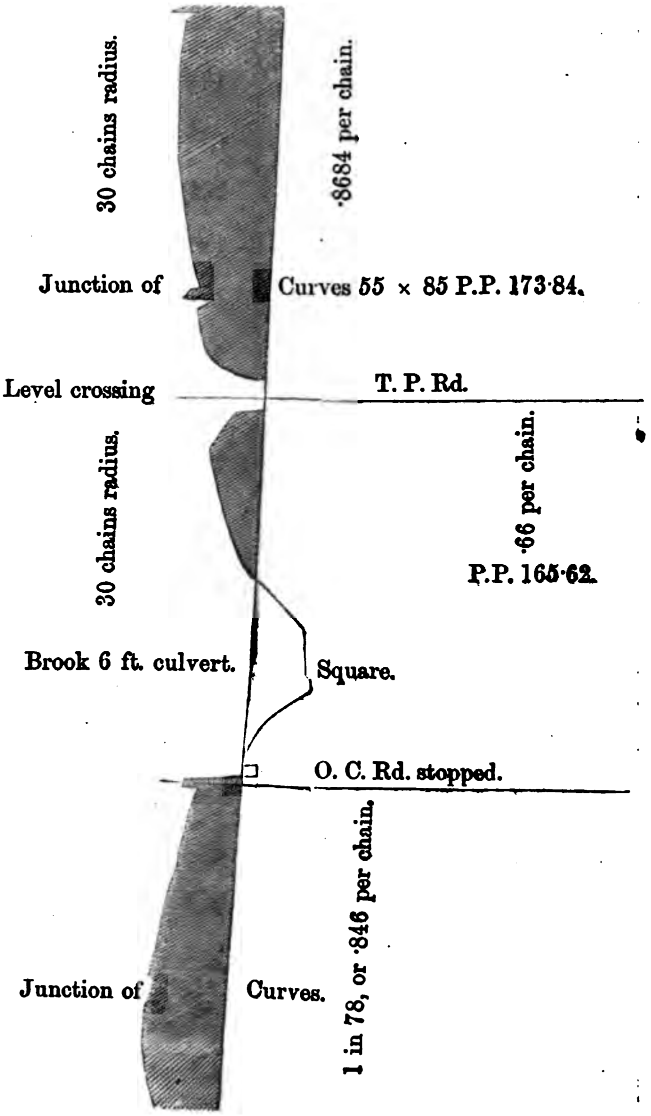
THE levelling book of the working section, with a correct sketch of the ground, or a pocket section, is constantly required on the works. The following is one of a most useful kind; it is prepared after the section has been plotted, and the gradients laid down. The angles formed by the nick with existing roads and rivers, or streams, should be entered, and the number of the drawing referring to the same as soon as prepared. The depths of cuttings and heights of embankments are also set down in their proper columns, and in that headed "distance" is noted the chainage where the nick intersects walls and fences. By the help of this, when stumps and level pegs have been long removed, their position with regard to distance may at any time be found. As soon as the widths have been set out, according to instructions given in the first part, these also can be set down in the half width columns; also the cubic quantities per chain in their proper column, as soon as they have been ascertained, which, where the earth work is heavy, particularly in sidelong ground, should always be admeasured from cross sections, taken at every chain stump, at the earliest opportunity. All bench marks given for the guidance of the excavators, masons, &c., should be entered in this book, with the date, as also any memoranda with regard to the nature or state of the works; it should be a register always ready for inspection, as well as for verification of the accuracy of his operations in very many respects.


P.P. 154·30.
Foundations 120.00 B.M. 122·00.
Centre of road √ 40·50.
Foundations 120·50.
40 chains radius.
1 in 76, or ·8684 per chain.
P.P. 145·64.
Viaduct.
47 feet from centre to centre.
·61 rise.
" 95.50
Foundation 52·50
" " 81·00
" " 105·00
B.M. 85·45.
P.P. 147·32.

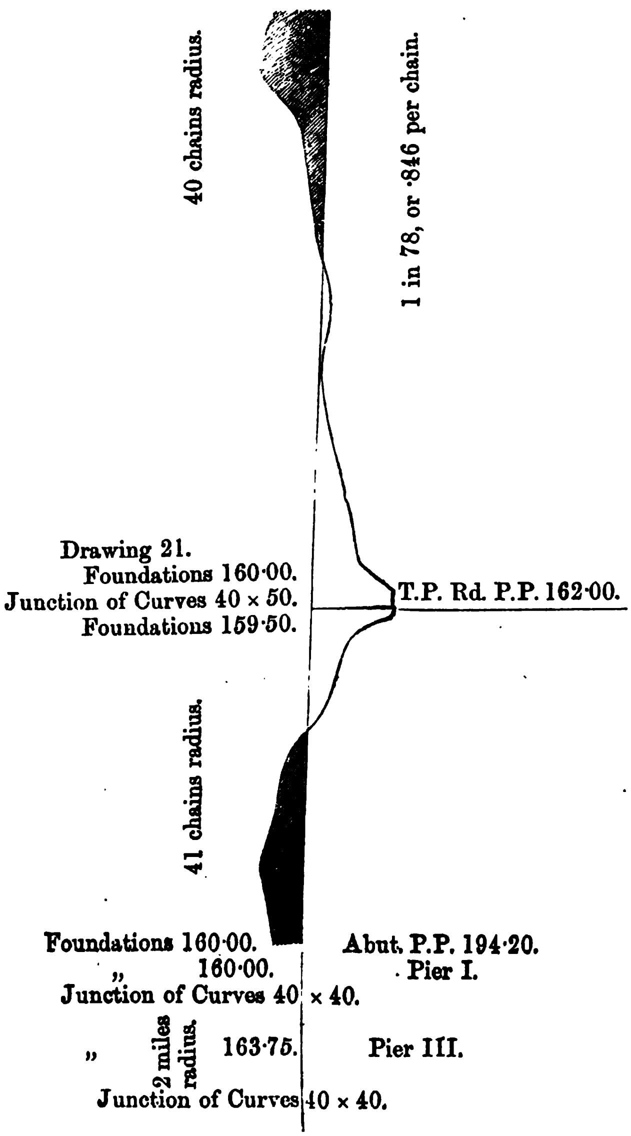
Half Widths.		Distance.	Total Rise.	Finished Levels.	Excavation.	Embankment.
Left.	Right.					
63.00	66·75	2 M. 39 Ch.	150·95	119·08	31·87	
61·00	64·50	40·00	150·50	119·94	30·56	
61·00	55·00	41·00	148·57	120·81	27·76	
		41·40				
64·75	58·00	42·00	150·33	121·68	28·65	
65·00	50·00	43·00	149·70	122·55	27·15	
63·50	50·00	44·00	152·14	123·42	28·72	
63·50	52·95	45·00	151·44	124·29	27·15	
60·65	48·55	46·00	151·13	125·15	25·98	
57·75	44·85	47·00	149·53	126·02	23·51	
53·00	40·70	48·00	147·95	126·89	21·06	
50·00	37·70	49·00	145·73	127·76	17·97	
43·75	34·30	50·00	143·88	128·63	15·25	
37·70	25·70	51·00	139·88	129·50	10·38	
		51·25				
36·50	28·25	52·00	141·13	130·36	10·77	
41·27	30·75	53·00	144·38	131·23	13·15	
44·45	33·20	54·00	146·38	132·10	14·28	
		55·00	122·40	132·97	- -	10·57
		56·00	52·30	133·84	- -	81·54
		57·00	102·80	134·71	- -	31·91
		58·00	9·42	135·57	3·85	
		59·00	152·20	136·44	15·76	


Junction of curves 75 × 88.
O. C. Rd. Square.
P.P. 161·11.
30 chains radius.
1 in 76, or ·8684 per chain.
P.P. 162·77.

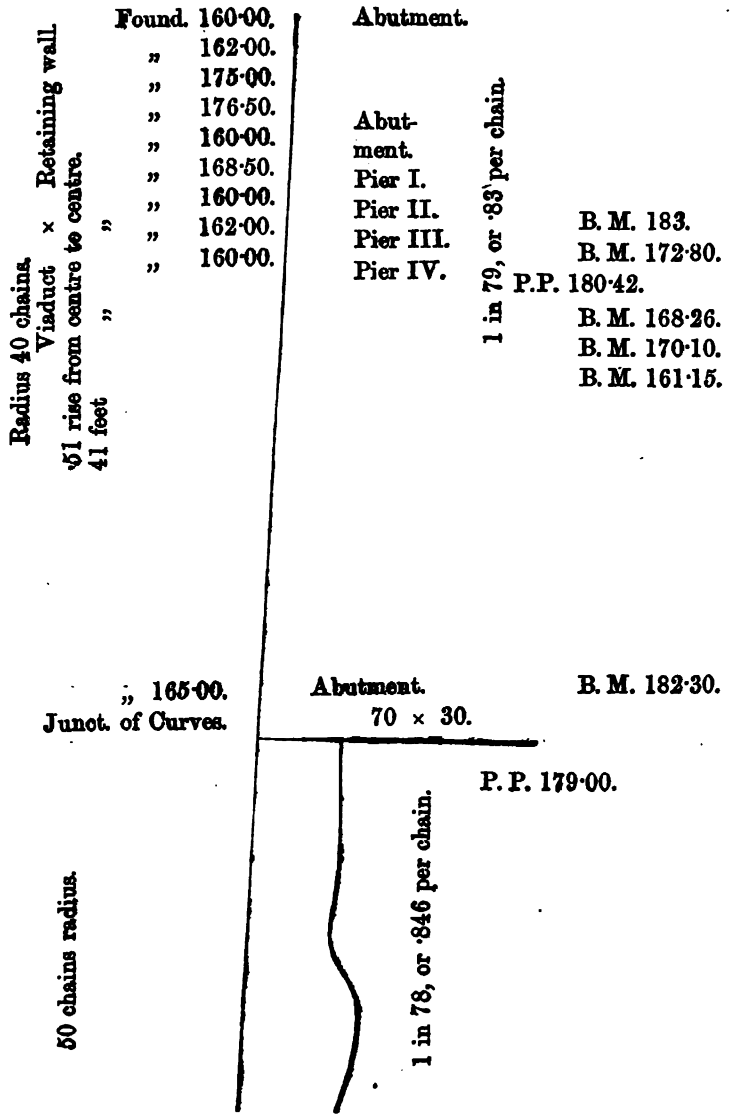
Half Widths.		Distance.	Total Rise.	Finished Levels.	Excavation.	Embankment.
Left.	Right.					
33·00	40·00	60·00	156·68	137·31	19·37	
43·50	42·50	61·00	159·12	138·18	20·94	
		62·00	162·39	139·05	23·34	
48·50	51·50	63·00	164·80	139·92	24·88	
		64·00	166·35	140·79	25·56	
49·50	59·00	65·00	166·65	141·65	25·00	
		63·30				
49·00	60·00	66·00	164·34	142·52	21·82	
43·70	56·00	67·00	164·54	143·39	21·15	
42·50	51·00	68·00	165·25	144·26	20·99	
38·50	47·65	69·00	163·65	145·13	18·52	
		69·70				
34·00	45·80	70·00	162·10	146·00	16·10	
33·00	45·00	71·00	161·85	146·86	14·99	
		72·00	163·13	147·73	15·40	
35·05	45·30	73·00	165·12	148·60	16·52	
		73·62				
		74·00	167·70	149·47	18·23	
35·75	48·00	75·00	167·91	150·34	17·57	
		76·00	171·04	151·21	19·83	
40·35	56·25	77·00	173·30	152·07	21·23	
		78·00	174·41	152·94	21·67	
44·00	59·00	79·00	175·77	153·81	21·26	
		3 Miles.	179·81	154·68	25·13	


30 chains radius.
·8684 per chain.
Junction of
Curves 55 × 85 P.P. 173·84.
Level crossing
T. P. Rd.
30 chains radius.
·66 per chain.
P.P. 165·62.
Brook 6 ft. culvert.
Square.
O. C. Rd. stopped.
1 in 78, or ·846 per chain.
Junction of
Curves.

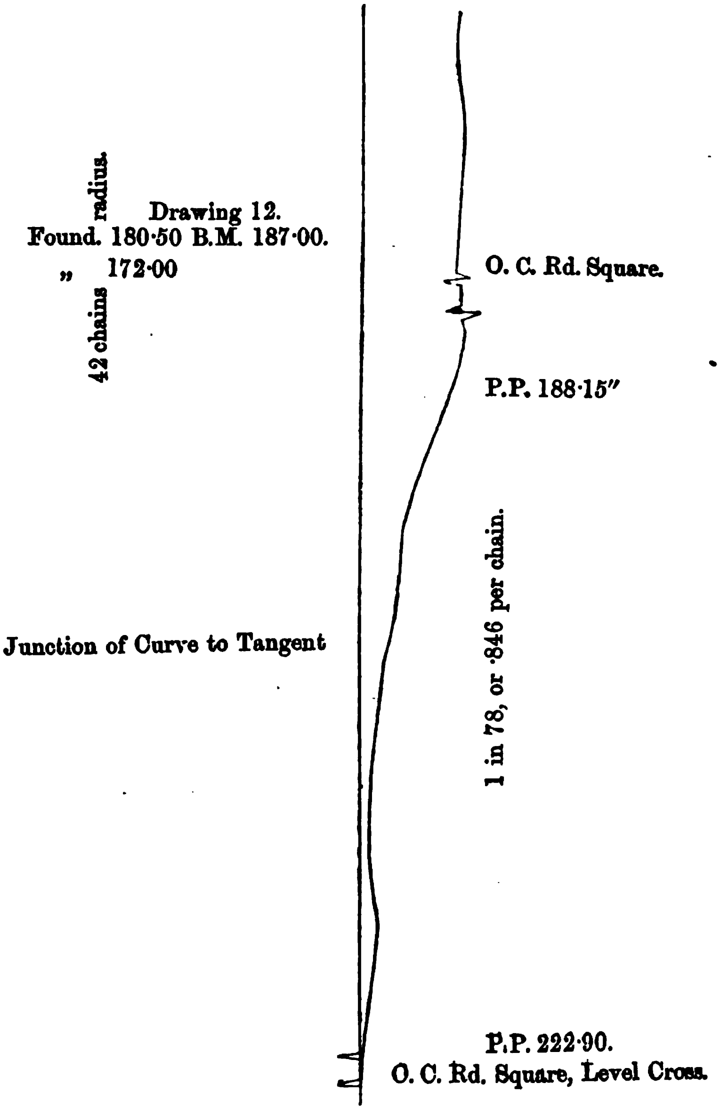
Half Widths.		Distance.	Total Rise.	Finished Levels.	Excavation.	Embankment.
Left.	Right.					
47·00	60·00	1·00	179·40	155·55	23·85	
47·50	59·00	2·00	181·64	156·42	25·22	
42·90	61·55	3·00	181·76	157·28	24·48	
43·80	61·25	4·00	182·10	158·15	23·95	
39·50	53·00	5·00	179·02	159·02	20·00	
36·40	51·00	6·00	177·50	159·89	17·61	
		6·10				
31·75	45·39	7·00	176·47	160·76	15·71	
		8·00	161·62	161·63		
27·75	41·25	9·00	174·54	162·29	12·25	
24·00	40·00	10·00	171·70	162·95	8·75	
18·75	38·00	11·00	166·39	163·61	2·78	
42·00	37·00	12·00	150·83	164·27	- -	13·44
		13·00	147·80	164·93	- -	17·13
		14·00	161·80	165·59	- -	3·79
		14·70				
24·50	24·00	15·00	172·12	166·25	5·87	{ Change gradient 646. }
		16·00	179·75	167·09	12·66	
		17·00	182·11	167·94	14·17	
		18·00	185·73	168·78	16·95	
		19·00	187·46	169·63	17·83	
		20·00	188·93	170·48	18·45	
		21·00	186·75	171·32	15·43	


40 chains radius.
1 in 78, or ·846 per chain.
Drawing 21.
Foundations 160·00.
Junction of Curves 40 × 50.
Foundations 159·50.
T.P. Rd. P.P. 162·00.
41 chains radius.
Foundations 160·00.
„ 160·00.
Junction of Curves 40 × 40.
Abut. P.P. 194·20.
Pier I.
„ 163·75.
2 miles radius.
Pier III.
Junction of Curves 40 × 40.

Half Widths.		Distance.	Total Rise.	Finished Levels.	Excavation.	Embankment.
Left.	Right.					
		22·00	185·41	172·17	13·24	
		23·00	190·41	173·03	17·38	
		24·00	180·90	173·86	7·04	
		25·00	179·42	174·71	4·71	
		26·00	177·22	175·55	1·67	
		27·00	174·05	176·40	- -	2·35
		28·00	174·29	177·24	- -	2·95
		29·00	176·70	178·09	- -	1·39
		30.00	175·67	178·94	- -	3·27
		31·00	172·56	179·78	- -	7·22
		32·00	170·00	180·63	- -	10·63
		33·00	161·07	181·47	{ Change gradient 83 per ch. }	20·40
		34·00	175·49	182·30	- -	6·81
		35·00	180·20	133·13	- -	2·93
		36·00	190·74	183·96	6·78	
		37·00	194·13	184·79	9·84	
		88·00	197·73	185·62	12·11	
		89·00	102·46	186·45		
		40·00	175·81	187·28		
		41·00	167·43	188·11		
		42·00	172·52	188·94		

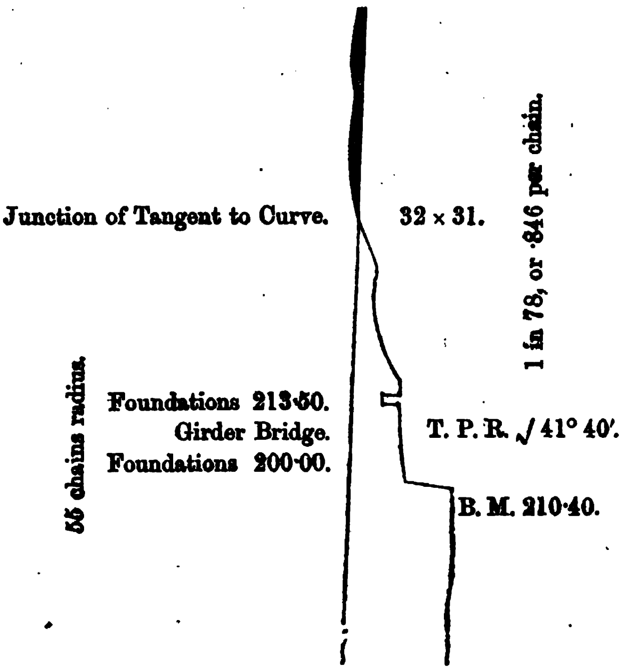

Radius 40 chains.
Viaduct × Retaining wall.
·51 rise from centre to centre.
41 feet " "
Found. 160·00.
" 162·00.
" 175·00.
" 176·50.
" 160·00.
" 168·50.
" 160·00.
" 162·00.
" 160·00.
Abutment.
Abut-ment.
Pier I.
Pier II.
Pier III.
Pier IV.
1 in 79, or ·83 per chain.
B. M. 183.
B. M. 172·80.
P.P. 180·42.
B. M. 168·26.
B. M. 170·10.
B. M. 161·15.
" 165·00.
Junct. of Curves.
Abutment.
70 × 30.
B. M. 182·30.
P. P. 179·00.
50 chains radius.
1 in 78, or ·846 per chain.

Half Widths.		Distance.	Total Rise.	Finished Levels.	Excavation.	Embankment.
Left.	Right.					
		43·00	171·62	189·77		
		44·00	177·75	190·60		
		45·00	182·79	191·43		
		46·00	185·27	192·46		
		47·00	174·52	193·09		
		48·00	170·50	193·92		
		49·00	165·53	194·76		
		50·00	165·58	195·59		
		51·00	158·49	196·42		
		52·00	172·77	197·25		
		53·00	168·09	198·08		
		54·00	175·37	198·91		
		55·00	179·79	199·75		
		56·00	177·73	199·96	{ Change gradient 84 per ch. }	22·23
		57·00	178·95	200·80	- -	21·85
		58·00	179·10	201·65	- -	22·55
		59·00	179·33	202·49	- -	23·16
		60·00	178·12	203·34	- -	23·22
77·00	79·00	61·00	173·35	204·19	- -	30·84
		62·00	174·10	205·03	- -	30·93
72·00	73·00	63·00	177·35	205·88	- -	28·53


Drawing 12.

42 chains radius.
Found. 180·50 B.M. 187·00.
„ 172·00
O. C. Rd. Square.
P.P. 188·15"
1 in 78, or ·846 per chain.
Junction of Curve to Tangent
P.P. 222·90.
O. C. Rd. Square, Level Cross.

Half Widths.		Distance.	Total Rise.	Finished Levels.	Excavation.	Embankment.
Left.	Right.					
65·00	67·75	64·00	180·25	206·72	- -	26·47
61·00	64·50	65·00	183·05	207·57	- -	24·52
63·00	66·00	66·00	182·88	208·43	- -	25·54
68·00	68·00	67·00	182·85	209·27	- -	26·42
		68·00	183·86	210·11	- -	26·25
65·50	66·00	69·00	185·77	210·95	- -	25·18
		69·40				
69·00	70·00	70·00	184·11	211·80	- -	27·69
65·50	65·50	71·00	187·12	212·65	- -	25·53
55·50	57·00	72·00	193·17	213·49	- -	20·32
47·00	49·00	73·00	198·57	214·34	- -	15·77
37·50	37·50	74·00	203·76	215·18	- -	11·42
35·00	36·00	75·00	205·75	216·03	- -	10·28
27·00	28·00	76·00	210·79	216·88	- -	6·09
		76·40				
25·50	25·50	77·90	212·34	217·72	- -	5·38
23·00	23·00	78·00	214·69	218·57	- -	3·88
20·00	20·00	79·00	216·75	219·41	- -	2·66
19·75	20·00	4 Miles.	217·52	220·26	- -	2·74
23·00	24·00	1·00	216·72	221·11	- -	4·39
19·00	20·25	2·00	219·61	221·95	- -	2·34
18·50	17·50	3·00	222·17	222·80	- -	·63
		3·65				
18·00	17·00	4·00	223·91	223·94	·27	


Junction of Tangent to Curve.
32 × 31.
1 in 78, or ·846 per chain.
55 chains radius.
Foundations 213·50.
Girder Bridge.
Foundations 200·00.
T. P. R. √ 41° 40′.
B. M. 210·40.

Half Width.		Distance.	Total Rise.	Finished Levels.	Excavation.	Embankment.
Left.	Right.					
17·00	17·00	5·00	225·48	224·49	·99	
19·00	20·25	6·00	227·94	225·34	2·60	
18·00	17·75	7·00	227·74	226·18	1·56	
17·00	17·75	8·00	228·57	227·03	1·54	
17·00	17·25	9·00	227·35	227·87	- -	·52
29·00	29·50	10·00	221·97	228·72	- -	6·75
29·50	31·00	11·00	222·01	229·57	- -	7·56
42·00	40·00	12·00	216·77	230·41	- -	13·64
		13·00	213·42	231·26	- -	17·85
68·00	71·25	14·00	204·80	232·10	- -	27·30
		15·00	205·08	232·95	- -	27·87
		16·00	206·20	233·80	- -	27·60
68·00	71·00	17·00	207·45	234·64	- -	27·19

The above portion of a section book shows part of a line now near completion; at page 67, chainage 2 miles 41·40, is a skew bridge, of which the angle is 40°·50′; at one side the depth of foundation is 120·00, and on the other side 120·50; a B.M. 122·00 above datum, was cut on the masonry which was 20 feet below the intended formation of over road. At 2 miles, 55·20 is the abutment of a viaduct with depth of foundation, 95·00; formation here being 133·15, the depth of foundation was 38·15 below formation; but the rise with the thickness of arch stone is 15′ 6″, springer 1 = 16′·6″ to be deducted from 38·15 = 21·65, or 21′ 8″ below springer, which height should be inserted on the contractor's memorandum-book, and signed by the engineer. The other piers and abutments should be treated in the same way. At 2 miles 64·00 is a junction of curves; two stumps, forming one line with the centre stump, have been driven in at the distance of 75 ft. on the left, and 88 ft. on the right, and these dimensions being booked, it is easy, as soon as required, to find this point, and to set out the curves for the permanent way. The same remarks occur further on, these distances being always marked by ×, the left side being always understood to be on one side of the line, and the right on the other, whichever way we may be looking, and this to avoid confusion of sides. These various notices of the requisite memoranda may appear trifling to old practitioners, but it must be remembered, that throughout these pages the information offered is not for them, but for those who have yet to learn, and these latter may believe the assurance made to them, that, in systematically keeping all these notes and memoranda, they will ensure the readiest and the best means of preserving their work from uncertainty and confusion.

Cross sections should be taken from right to left, or left to right, through the centre line, particular care being given to note in the field-book the direction in which this has been done, that they may be plotted in the same direction, and that it may at all times, and by any one, be known which is the right or left of the line shown by these sections; it is scarcely more necessary to add, that the chainage and levels at the centre must in particular be noted, in order that the proper depth may be set off at the distance, to show the quantity of excavation, or embankment; for this purpose a cardboard templet, with a base of 30 ft., 31 ft., or 33 ft., as the case may be, made to a suitable scale with the slopes cut to the "ratio of slope," as 1 to 1, or 1½ to 1, as may be determined upon, will be found an accurate and expeditious little instrument. Fig. 1 will at once explain this. They must always be plotted to a natural scale; 20 ft. to the inch will not be found too large for accurate admeasurement of the sectional area, and for checking the setting out of slopes when this latter operation has been previously done. The cross sections must all be carefully numbered, and the

FIG. 1.

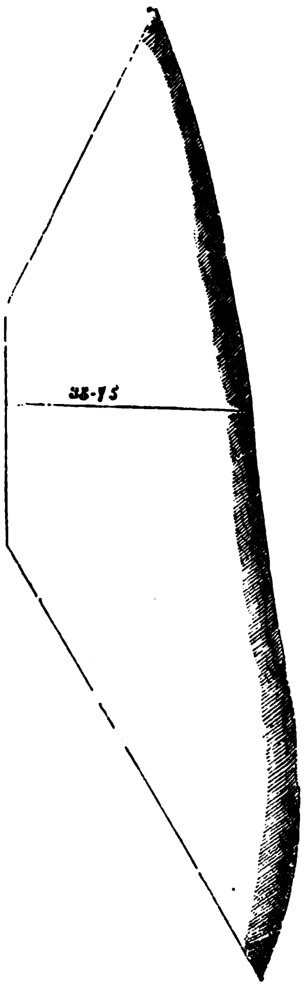


FIG. 2.

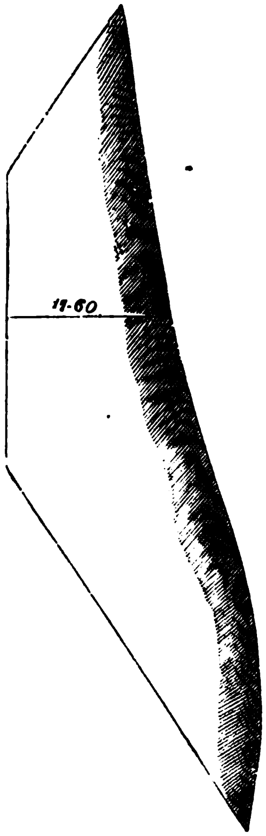
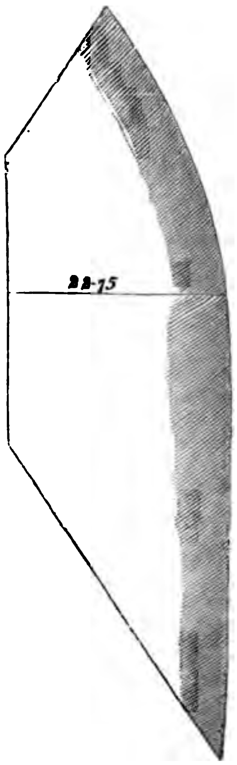


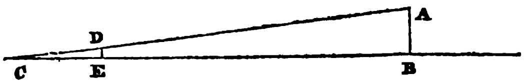
FIG. 3.



numbers entered on the pocket section at their respective chain stakes. Where side cutting is expected, the cross sections must be produced, so that the quantities of excavation may be accurately ascertained therefrom. The levels for these cross sections must undeniably consume considerable time, but with irregular surfaces, as shown at Figs. 2 and 3, what other means are there of correctly ascertaining quantities? In one case the contractor suffers, and in the other great injustice is done to the Company. Again, in cuttings of 30 ft., 40 ft., and 50 ft., where the spread from edge to edge of the slopes would be from 120 ft. to 180 ft., it is next to impossible when measuring up to obtain this length with accuracy, particularly in sidelong ground, and if we have a curved surface matters are still worse; hence difficulties, disputes, and litigation. Even before the completion of works it is so easy, in case of uncertainty or variance in admeasurements, to set off any excavation in whatever state, and to obtain true quantities, that these documents are really invaluable. At the end of this work will be found tables of sectional areas for the calculations of earthwork from these cross sections.

An inclined plane is one inclined to the horizon, and by the term "gradient," numerically expressed, we imply the proportion which the height of rise or fall of the inclined plane bears to the length of the said incline, as 1 in 100, 1 in 200, 1 in 300, are expressions which mean, that in 100 ft. the rise or fall is 1 ft., that in 200 ft. the rise or fall is 1 ft., &c. &c.; and by keeping 1 as a constant number, the various proportions which inclined planes bear to each other is better expressed and understood than by varying both expressions, or employing fractional quantities. Having to ascend or descend to a given point above or below the starting point, and along a given route, we shall know by levels and measurements the height of ascent or descent, and the distance by which the difference of levels will be regulated into one or more inclined planes; for a short distance, and slightly undulating ground, this may often be done by one incline; for any considerable length, more particularly in a broken country, hills and valleys, rivers, canals, and roads, will compel us to consider these as guiding circumstances, or we must encounter innumerable tunnels and viaducts, and disproportionate cuttings and embankments, expensive bridges, and other crossings; but a well regulated series of inclined planes, graduated in a measure, proportionately to the inclination of hill and valley, skirting along the one and skimming over the other, and reaching from height to height, enable us, by moderate works, and therefore at a moderate expense, to attain the desired end; and generally the reaching from valley to hill, and hill to valley, the crossing of rivers and roads, the equalization of excavations and embankments, will be the existing circumstances in compliance with which certain heights are to be reached, and by which the inclined planes, and therefore the gradients, will be determined. The working section will show a vertical plane passing through these various points, the relative heights of which have been ascertained by levelling, and their distances from each other being known, it remains to calculate the gradients. At distance 3 miles 8·00, there is an incline which is to reach from 161·64 above datum to 14·50 above a road, which is 6·50 chains further on; the level of the road is 151·43 above datum, and 151·43 + 14·50 = 165·93; but 165·93 = 161·64 + 4·29, or the difference of level between a point we have reached on the section and one to be attained. But 6·50 chains are equal to 429 ft., and this divided by 4·29, the difference of level will give 1 in 100 for the gradient; for 4·29 : 429 :: 1 : 100, or AB : BC :: DE : EC; therefore,

FIG. 4.



in all cases, to find the ratio of inclination, or gradient, divide the length in feet by the rise or fall, and the quotient will be the answer; but having the gradient, or ratio of inclination, it is also necessary to know the rise or fall per chain, in order to calculate the depth of cutting or embankment, or rather the height of formation above datum, as this height, deducted from that of the surface above datum, will give the depth of cutting whilst the deduction of the height of surface from the height of formation will give the depth of embankment, as at 2 miles 10 chains 171·70 − 162·96 = 8·74, or depth of cutting; and at 2 miles 12 chains 164·28 − 150·83 = 13·45, or depth of embankment.

To find the rise or fall per chain, divide the difference of level by the number of chains in the incline, as 4·29 + 6·50.

6·50)4·290(·66
3900
3900
3900
0000

Therefore, to find the gradient, or ratio of inclination, divide the length of the incline in feet by the difference of level. And to find the rise or fall per chain, divide the difference of level by the number of chains, as shown above.

The ratio of inclination of a plane, or the gradient, being given to find the inclination per mile, divide the number of feet in a mile by the ratio, as

100)5280(52·8 per mile.
500
280
200
800

The gradient being given, to find the inclination in a chain, divide 66 (the number of feet in a chain) by the ratio as for 1 in 100, 66 ÷ 100—

100)660(·66
600
600
600

Also, the gradient being given, to know the rise or fall per yard, divide 3 (the number of feet in a yard) by the ratio, as in 1 in 100, what is the inclination per yard?

100)300(·03
300
000

And at any time, for any length, divide the length in feet by the ratio, as in 1 in 78, how much in 12?

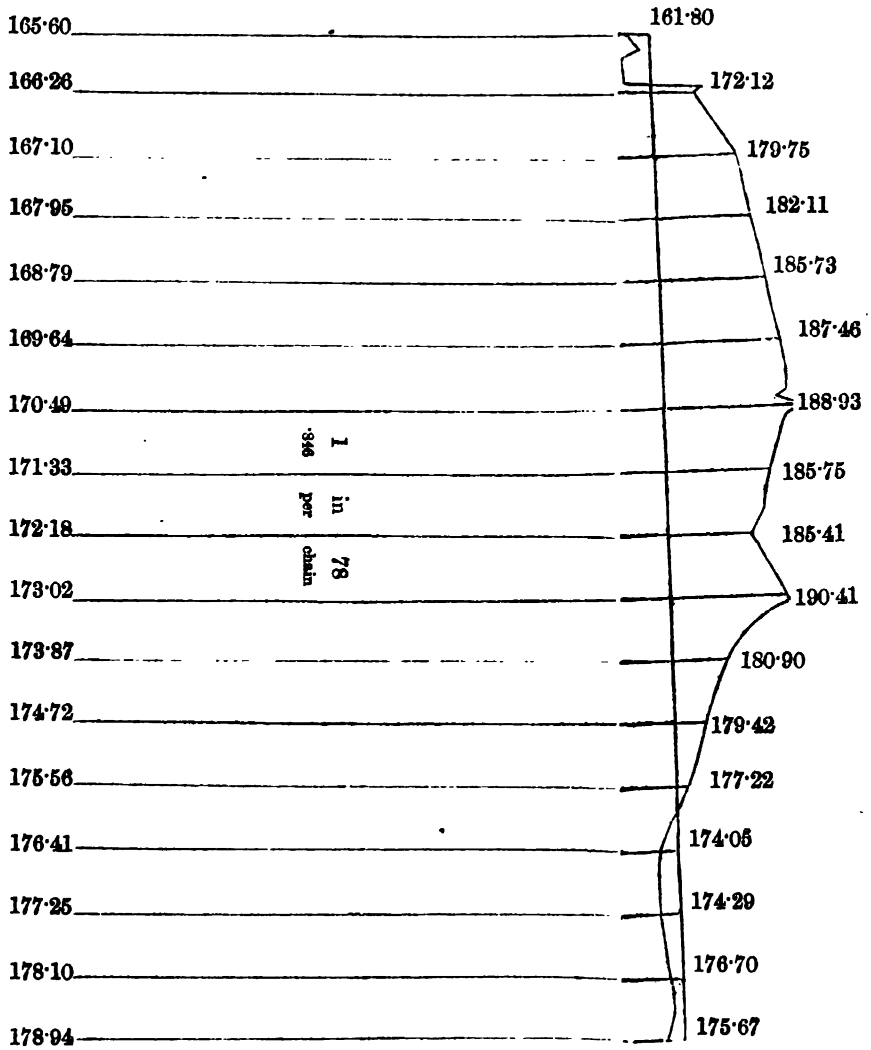
```
78)12·0(·15 (sufficiently near for practice)
   78
   ---
   420
   390
   ---
```

In calculating the formation heights for the contract section, from which, as before observed, the depths of cuttings and embankments are afterwards ascertained, the greatest care is required in doing this correctly, for if, in this first step, an error be committed, it will be carried on into the depth of cutting or embankment, and the contractor working from such contract section may cut to a wrong depth, for which, in justice, he is in no way to blame; to men of habits at all careful, this may appear almost impossible, but it is nevertheless, however gross the blunder, one of common occurrence. At 2 miles 33 chains, let it be supposed that the formation height is marked 182·48 instead of 181·48, which it should be; now the heights for the springers would be set out by reference to bench marks, when the arch might be turned to a height of 21·41, instead of 20·41, making the crown of the arch 1 ft. too high for 181·48 − 161·07 = 20·41; but 182·48 − 161·07 = 21·41. It is hoped that the importance of a careful calculation of the gradients at every chain stake is now distinctly understood; the ratio of inclination being ascertained, and the rise or fall per chain, every stump height will require to be calculated separately, and checked by tens, twenties, &c., and in as many places as possible. The reader may rest strictly and honestly assured that, for whatever trouble 20 or 30 miles of such calculations may give, he will be most amply repaid by ease of mind on this important subject during the working of the contract. From formation height 161·64, before referred to, we have an incline of ·66 per chain for 7 chains; and ·66 × 7 + 161·64 = 166·26; but 161·64 + ·66 = 162·30 + ·66 = 162·96 + ·66 = 163·62, and so on until we have 166·26 at the 7th chain, if no error be made; on an incline of a greater length we check these results by multiplying the rise or fall per chain by 10, 20, 30, &c., which is very quickly done, and examining the 10th, 20th, or 30th chain stakes taken at different places. This being gone through, it only remains to get the depth of cutting by deducting formation height from the surface height, or the reverse, when we get the height of embankment.

The pocket section being prepared so far, we should, as soon as the works of construction are determined on, insert notes from the working drawings or otherwise, or the angles of skew at which the line crosses roads, canals, &c., the spans of arches on the square and skew, the rise of the arch, the depth of arch stones, of puddle, if any; also, if the works be on an inclined plane, the rise or fall from centre to centre of piers; memoranda also, of nearly similar nature, should be made of girder bridges, culverts, drains, and other works occurring along the line. These remarks are more than necessary, because, when on the works, the drawings, when required, are often mislaid, or partially defaced or destroyed; it must be added, however reluctantly, that the tracings with which contractors are supplied, are often wrongly figured, and the site of construction, amidst the moving to and fro of masons, labourers, and "navvies," is not the place where such errors may be most readily detected and corrected. The acting engineer always affixes his signature to the working drawing, but not always to the tracings, the correctness of which is often entrusted to a confidential office assistant, but who, from want of field practice, is not always aware of the value of correct figures. The "Assistant Engineer" will find it advantageous, and only consistent with his duty, to compare the copy of contract works with the office original. Whilst on this subject it may be as well to mention, that the advice and hints thrown out in these pages are for the guidance or consideration of the "*Assistant Engineer*," who may also, *to a certain extent*, have to perform the duties of contractor's agent, which will always be the case when the works of a line are sub-divided into numerous small contracts, a circumstance now of no rare occurrence; and in this case the engineer will find his duties and responsibilities doubly onerous. Reference to the extracts made from a pocket section will explain, fully it is hoped, the nature of the remarks required with regard to the contract works; their practical application will be more fully explained in the course of the following pages.

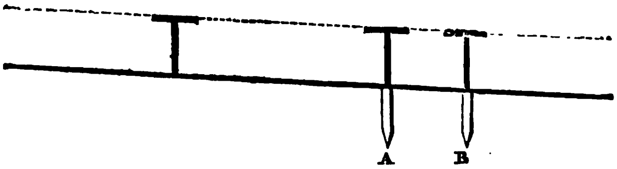
The contractor is supplied with a copy of the contract section of the intended line of railway, or any portion of it, the performance of the works on which is entrusted to his execution, and if the levels are set out by his agents, the engineer has but to check them, a simple matter merely demanding correct levelling; but he may have to set out

FIG. 5.



the bed moulds, which should be done in the following manner:—take Fig. 5 for a cutting to be worked from both ends. At stump, 2 miles 27 chains, we are to have for formation 176·41 above datum, and the height of surface is 174·05; plant the level at a convenient point, and direct the levelling staff to be held on the level peg at 174·05, and read off, say 7·00; but 176·41 − 174·05 = 2·36 for height of embankment, and 7·00 − 2·36 = 4·64; now if the staff be raised until we read through the telescope 4·64, it is very evident that the foot of the staff will be held at 2·36 above the surface, or at 176·41 above datum, or formation height; next, direct the staff to be moved along the nick or centre line, and towards the cutting, until we read off with the level 4·64 again, we shall then have found along the nick a point exactly level with the intended formation height at 176·41; but our gradient is 1 in 78, or ·846 per chain; the formation therefore at the point sought will be lower than 176·41 by 1 in 78, according to the distance from 176·41; let this distance be half a chain, the formation height will then be $176{\cdot}41 - \frac{846}{2} = 175{\cdot}99$, or ·42 lower; and if we add this ·42 to 4·64, we shall have 5·06; move the staff nearer until with the level this depth 5·06 be read off, when we shall have the desired point; for if when we first read 4·64 the foot was at formation height, as I hope I have made evident, by adding to it ·42, and reading off 5·06, we have a point ·42 nearer to datum at half a chain distant, and therefore parallel with the incline; and this point found, drive in a stake about 3 in. diameter, until on reading off the staff we have 5·06, and another at 176·41, until we have 4·64, and we shall have two stakes at the required formation height half a chain apart, and by boning from these two heights any tolerable excavator can direct the formation of the bottom of his cutting until fresh levels are given. Boning is performed with boning rods, which exactly resemble T squares, in the following manner:—let A and B, Fig. 6, be two stakes driven to a certain depth, and according to a given inclination; if on both of these stakes boning rods, of exactly equal length, be held perfectly upright, it is plain that the tops of these

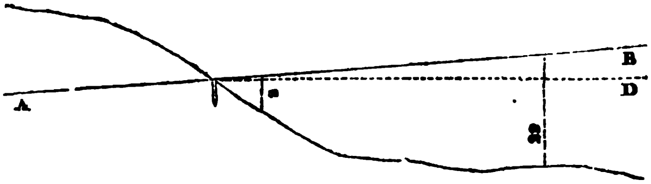
FIG. 6.



will be parallel to the incline, and if a third rod be carried along the intended slope, the top of it will be in line with the top of the other two, if the incline be correct; if it is above there will be more to cut away, and if it is below the excavation will have been made too deep; this method is certainly but approximate, but quite sufficient to guide the excavators for a time. As another example of setting out the bed moulds, we will take the other end of the cutting Fig. 5. At formation 165·60 we have the surface height of 161·80, and therefore a bank of 3·80, plant the level, and then the staff on the level peg, and read off, say 9·50; but 9·50−3·80=5·70, and if the staff be held up until such depth be read off, then again will the foot of it be at the formation height at this point; move the staff along the centre line until this 5·70 be again read off, and we shall have a point level with the intended height of embankment; but the gradient here being 1 in 100, the new point sought must be higher in that proportion, as we are now rising, and the distance is 52 ft.; for this distance the rise will be ·52, and as we are *rising*, be it remembered, we must deduct ·52 from 5·70, when we shall have 4·18; by moving the staff along the nick until from the level we read off 4·18, we shall find the new point for formation, at which drive in a stake. Under no circumstances should this part of the work ever be considered as completed until carefully checked, which should be done by carrying on the levels to the nearest P.P., or permanent post.

The incline for the cutting being given, will be, however, but an indifferently approximate guide for the height of an embankment, particularly if of clay and tipped in dry summer weather, for, under such circumstances, such an embankment may be expected to settle one-fifth of the height at which it is first formed; let Fig. 7 be a sketch of a cutting and an embankment, in which suppose A B the inclined

FIG. 7.

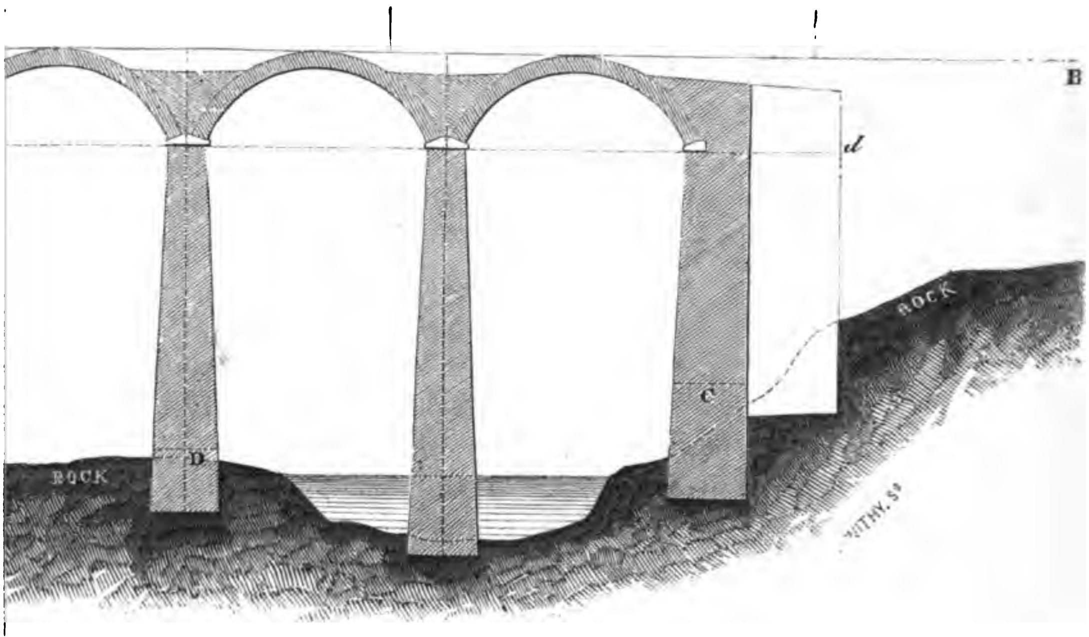


plane, and the required formation height at B C to be 22 ft.; if the embankment be formed at once to this height, and the above-mentioned settlement before perfect consolidation takes place, and it will not be much less, the general height will be something like A D, and will require reforming; it is therefore absolutely necessary to keep the bank high in proportion to the expected settlement, whatever may be the material of which the bank is formed, and a near approximation of the depression may be very easily ascertained a few weeks after the tipping has commenced, due allowance being made for extremes of weather. At 1 chain from the cutting we have embankment height of 8 ft.; as soon as the tip is formed beyond this point, ascertain the height by levelling; a few weeks after, the depression from the weight of the earth and that of the loaded wagons may be ascertained by levelling again, when an approximate ratio of settlement will be determined, by which the formation of the embankment may be directed.

Viaducts and bridges are works which require the greatest accuracy as regards levels, and an error of this description is truly unpardonable, as attention and care are all that are required to carry the construction to the proper height; settlement in the masonry will of course take place, but unless the work is very bad, or the foundation vicious, the difference of level occasioned by this settlement will be immaterial: by attending to the following advice the heights of the crowns of the arches will be found to be perfectly accurate. Fig. [illegible] is a sketch of a section of a viaduct; A B is the gradient of 1 in 100, or ·66 per chain; the span of the arches is 35 ft., the rise is 13 ft., and the thickness of the voussoirs, *Anglicé*, arch stones, is 2 ft.; the piers, including the springers, must all be built up to 13 + 2 below formation, that the line under the springers may be parallel to formation. At A we have formation height 340·00, surface height 345·00, or a cutting of 5 ft.; near this we have a permanent post, or P.P. 343·59, or 3·59 above formation at A; plant the level, and let the staff be held on the P. P., read off, say 5·25; send the staff on to A, or to *b*, which will make the work much shorter, and this point may be pretty nearly ascertained by the eye; supposing the staff, therefore, at or near this latter point, read off, say 8·00; 8·00 – 5·95 = 2·75 fall, and 343·59 – 2·75 = 340·84, or ·84 higher than 340·00, and also, therefore, ·84 higher than a point level with the required formation; now, by moving the staff lower down, so that 8·84 be read off, we shall have a point level with formation at A, for 8·84 − 5·25 = 3·59 fall, and 343·59 − 3·59 = 340·00. Now measure the distance from stump 340·00 to the point where the staff was last held, and say it is 15 ft.; the inclination for this distance being ·15 rise, the required height for formation will be 340·15; but the height of permanent post is 343·59 − 340·15 = 3·44, and when the staff is held on the P.P., we read from the level 5·25; add to this 3·44, when we get 8·69. Now drive in a stout stake, iron hooped, at the said distance, until the staff being placed upon it, we read off 8·69, and it will be at the required height, for 8·69 − 5·25 = 3·44 fall, and 343·59 − 344 × 340·15. It has been already observed, that a line drawn along the tops of the piers and abutments under the springers must be 15 ft. below formation height; now it will not be sufficient to deduct this 15·00 from 340·15, giving 325·15, and drive in a stump at that height, because we cannot do so vertically under *b*, and at *c* an allowance must be made for the inclination of the gradient corresponding to distance. But by levelling from *b* downwards to *c*, we can find the height 325·15, which will be level with a point 15·00 below *b*; measure the distance from A to *c*, call it 30 ft., the inclination for which being ·30 we shall have 340·30 for formation at this point, and 340·30 − 15·00 = 325·30, to which height drive in a stake as before, and then check by levelling back to P.P. 343·59, which height exactly we shall get if the work has been done correctly. From the appearance of Fig. 8 the reader may be led to think that the above-mentioned stakes are driven on the centre nick, but as in this position the excavators would dig them up, they are driven in some 15 ft. on one side; in rock or sound soil these bed moulds are little liable to disturbance, but they are not so safe in a loose ground, and it is always better occasionally to check their heights. If at the other side B of the viaduct the ground was similarly high, we should have but to repeat a set of levelling operations analogous to the last, to get the lines A B and *c d*, but being in embankment this cannot be done, and we must employ another method; the remarks required with regard to the depths of foundations, &c., will be noticed here after. We will suppose that at abutment C, and pier D, the masons have reached the heights marked by the dotted lines, we must first ascertain the formation heights at those points, and they are 341·66 and 342·45, and these minus 15·00 will give 326·66 and 327·45 for the heights at the springers. By levelling from a P.P. we find that the height of the abutment at C is 290·05; 327·45 – 290·05 = 37·40, or the height below springers to which the masons have reached, that is, that they have 37·40 ft. of masonry to put on to reach springing height, and this height, 37·40, should be entered in feet and inches by the engineer on the foreman's or sub-contractor's book, and a similar memorandum with the date should be entered on his section. At pier D the height of masonry is ascertained by levelling to be 277·76; and 326·66 – 277·76 = 48·90, the depth at D below springing, and this depth should be similarly entered; and in both cases a crow's foot-mark /|\ should be made on the face of the masonry where the levelling staff had been held, that it may be found at any future period. When the piers have reached within a few feet of their due height, it is well again to take the levels, as by then giving the height to be added, the masons or bricklayers, but of course more particularly the former, can regulate to a nicety the depth of their courses, and some allowance will have been made for settlements.

As soon as the foundations have been excavated to the depth required, the level to the bottom should be ascertained, and entered on the section-book as so much below the springing, and this depth should at an early opportunity be transferred to the drawing. On no account, either in viaducts, bridges, retaining walls, or other constructions, should this precaution be neglected, as the depths can then at any time be ascertained for measuring up.

Fig. 1.



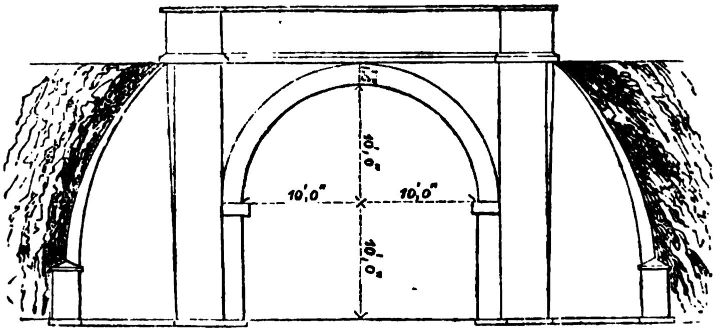
CHAPTER V.

SETTING OUT WORKS ON THE SQUARE, ON THE SKEW, AND ON CURVES.

The constructive works on a railway consist principally of bridges and culverts, viaducts and tunnels, and retaining walls; and these are either on the square or on the skew, on straight lines or on curves. We will endeavour to point out the methods employed in practice for setting out these works under these different circumstances.

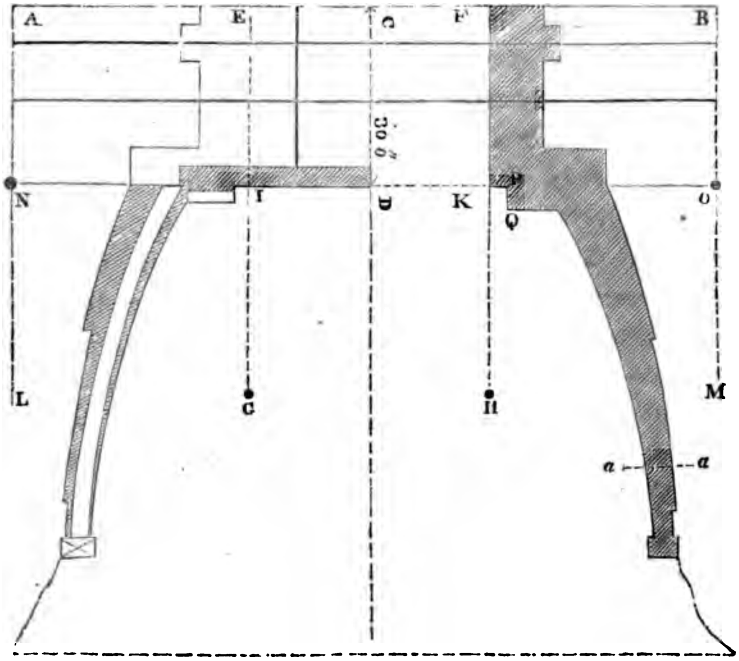
As the first case in bridges over or under roads, we will take the bridge, Figs. 1 and 2, intended to carry the railway over a road; the road is at right angles to centre line or nick A B, and the bridge will therefore be on the square; also the centre line of railway is straight; the span of the arch is 20 feet, and the half width of the bridge from the centre to the outside of the parapet is 15 feet, as C D; the face of the abutment will therefore be 15′ × 2 = 30′. The centre line being stumped out, we have only to transfer the dimensions in the drawing on to the ground; set out the centre C, which will be in the middle of the road, unless any particular circumstance render it advisable to place this centre nearer towards A or B. But we will suppose it at C, and of course in the centre line of railway; from C set out 10 ft. towards A at E, and the same towards B at F, when we have the span set out; from E and F, set out E G and F H, both accurately at right angles to A B, the centre line, and upon E G and F H measure off 15 ft. for half the width of the faces of the abutments, as at I and K, and measure the distance I K, which should be 20 ft., if the first distances C E and C F have been accurately set out, and if E G and F H are both at right angles to A B, repeat the same operations on the other side of A B, and, if the lines be accurately set out, we shall have G I E and H K F both produced; this being done, drive in stumps at G and H, and at G I E, and H K F, both *produced;* and note that these stumps must be out of the way of the excavators, as by these stumps the masons have to line out the faces of the abutments. Now from the nick or centre line again, and at 30 or 40 ft. from the centre C, as at A and B, set out A L, and B M, also accurately at right angles to A B,

FIG. 1.



and upon A L and on B M measure off 15 ft. again as at N and O, when N I K O will be one straight line, and drive in stumps at N and O, do the same thing again on the other side of A B, and we shall have the principal lines and dimensions set out—namely, the centre line A B, the faces of the abutments E I, F K, and the half width of the bridge by N O, also at any time when the centre line A B may be obtained; by these lines we may set out all the other dimensions. We have now to give the length of the wing walls, which length will depend on the height of the embankment; in this case it is 21′ 6, at slopes 2 to 1; this gives 43 ft. from the ends I and K of the abutment to the foot of the bank; but we have the newel, which is 4 ft. high, and which is constructed back into the embankment at the distance from the foot of 4 × 2 the ratio of slope = 8, and therefore the length 43 ft. − 8 will become 35 ft. for the length of the wing walls, which should also be stumped down; the distance K P is equal to the depth of the arch stones; see the elevation, and the length P Q depends on the batter or slope to be given to the pilasters; we will say 1 inch per foot, when, since the pilaster is 21′, 6″ in height, this being the depth of bank, we shall have 21½ in. of batter; to this must be added 3 in. for the projection of the short pilaster above the string course, and we shall have 21½″ + 3″ for the total projection of P Q. But this is on the supposition that the site of the bridge is perfectly level, which it is very likely not to be; Q may be 2 ft. lower, and 21½ will become 23½, or Q may be 3 ft. higher, when we must deduct 3″, and make 21½ 18½, and every one of the four pilasters may be at different levels from

FIG. 2.

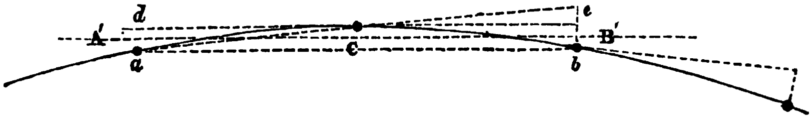


the centre, and therefore would require a different projection for their batter. This last remark refers to wing walls exactly in the same way; for which reason we always "set out the slopes" at every road or site of bridge, and the difference of level being then correctly allowed for, we have but to multiply the height of the newel by the ratio of slope, say 4 × 2 = 8, and set out the end of the wing wall at 8 ft. inside of the foot of the embankment; when working drawings have been plotted without cross sections, these deviations from the drawings are almost interminable. We will suppose, for instance, that in consequence of the ground rising, the end of the wing wall comes at *a a*, instead of where it is shown at Fig. 2; we should have to transfer the thickness of the wing as shown on the drawing at the newel to this new situation for it, which would alter the dimensions all along; a short practical rule for determining the mean thickness of wing walls, is to multiply the height by ·25, which will give a quarter of the height for the *mean* thickness: for heavy masonry, ·22 will be sufficient. In setting out the wing walls, an allowance must be made for batter according to height, if an inclination is to be given to them. In the simple case which we have had under consideration, it is scarcely possible to commit any error; but we have been minute, because if the dimensions were all treble, we should proceed by the same means.

In setting out, measuring rods are far preferable to tapes, and we also use about half-a-dozen short boning rods, about 5 ft. long, or wooden pegs, and a good line, which may be procured from the masons; and in setting out a right angle, where the lines are long, we also make use of a box sextant, which is *most accurate, quickly used, and may, without being felt, be carried in the pocket;* in short, we strongly advise the assistant-engineer to neglect no means to make his work accurate, and to employ every mechanical means which may aid him in doing this; the rapidity also with which the various operations of setting out are performed will depend upon his knowledge of the application of mechanical means.

As a second case, we will set out a bridge carrying the railway over a turnpike road, and a stream running by the side of it; the centre line of railway is on a curve of 60 chains radius, and the road is at right angles to the centre line. Let Fig. 3 be the curve; if we were to set out the faces of the abutments at right angles to this curve, we should have a conoidal instead of a cylindrical ring for the arch, and the span at one end would be considerably greater than at the other. If we were to set out the work in this manner, it would be by setting out perpendiculars at right angles to the chords, and these perpendiculars would not be parallel, because the contiguous chords are not parallel; to overcome this obstruction, it is usual in practice to proceed in the following way:—Fig. 3 being a curve of 30 chains radius, the offset,

FIG. 3.



when setting out by chords, would be 13·2 in inches, and if setting out by tangents, it would be $\frac{13 \cdot 2}{2} = 6 \cdot 6$; set out one quarter of 13·2, or one-half of 6·6, which is equal to 3·3 in inches; from stump *a* and

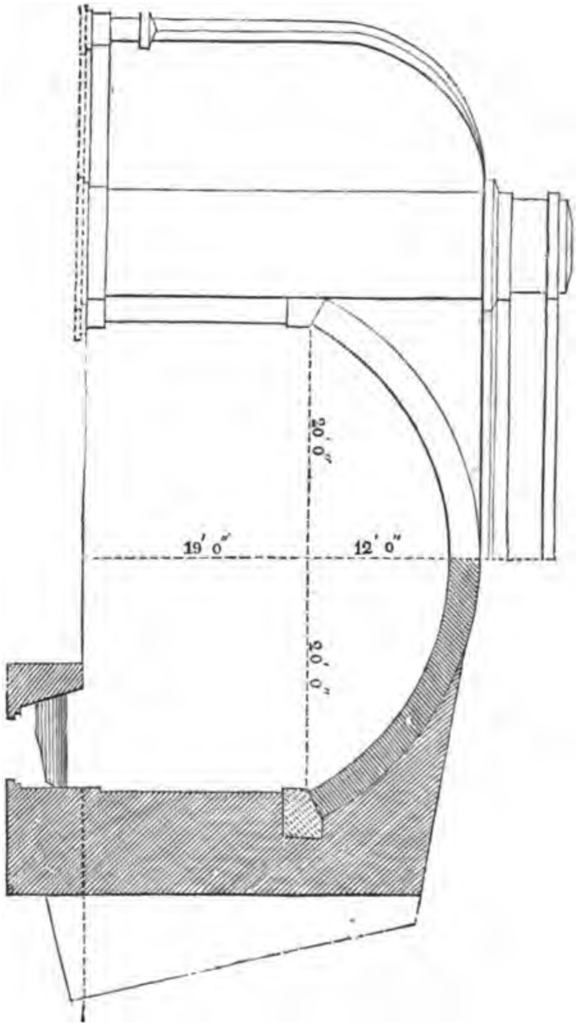


FIG. 4.

stump *b*, towards the outside of the curve, set out 3·3 as at A and B, and from stump *c* set out the same dimension 3·3, toward the inside of the curve at C; we shall thus obtain a line, A C B, which will be at a mean distance between the chord *a b*, and the tangent *d e*, and on which we can set out the dimensions of our bridge on the square. Now let

A C B, Fig. 5, represent A′ C′ B′, Fig. 3; we proceed by first setting out the span of 40 ft., 30 ft. for the width of the turnpike road, and 10 ft. for the width of the stream, on account of which latter the centre of the arch will not be over the centre of the road: E C F being the span of 40 ft. on the straight line A B, set out E G, F H at right angles to A B; produce the line thus sighted to the other side of A B, set out the half faces of the abutments, measure from face to face at each end, that the spans at each side of the bridge be equal; set out I K, at 15 ft. from the centre line A B, and on each side of it, and see that these points are perfectly in line with each of the faces of the bridge; we have now found our principal lines, and have but to set out the batter of the pier with due attention to the projection for batter being proportioned to inclination per foot and height of each pilaster relative to the centres of abutments E and F.

Wing walls are built to prevent the earth in the slopes of the embankment from spreading over the road, and it is necessary that they do this effectually, without danger of being overturned or deformed by bulging out. It was customary some years since to give them a considerable spread, thereby increasing the quantity of masonry, besides making a bridge of a single arch, quite a secondary feature in comparison to its outspreading and overshadowing wings. It is too common a practice merely to mark out on the ground the extreme length of the wing wall, and to leave the foremen of masons to settle the rest as best they may. From long practice on railway works many of these men possess a knowledge deduced from experience, which they apply with an intelligence and earnestness deserving of great esteem; but there are also a greater number of them who are totally ignorant of all practical means for doing the work, unjustly left to them by idleness or ignorance equal to their own; and but too often the result is a wing wall of crooked curvature, with a tumbling appearance which would do credit to the efforts of a thousand years, to say nothing of the real weakness of such brickwork or masonry, if it deserve not rather the name of a heap of rubbish. The following methods will be found as practical as they are simple: set out the projection of the pilaster *a b*, and the return, and make *c d* equal to the width of the pilaster, and parallel to F H, by measuring off from the face of the arch

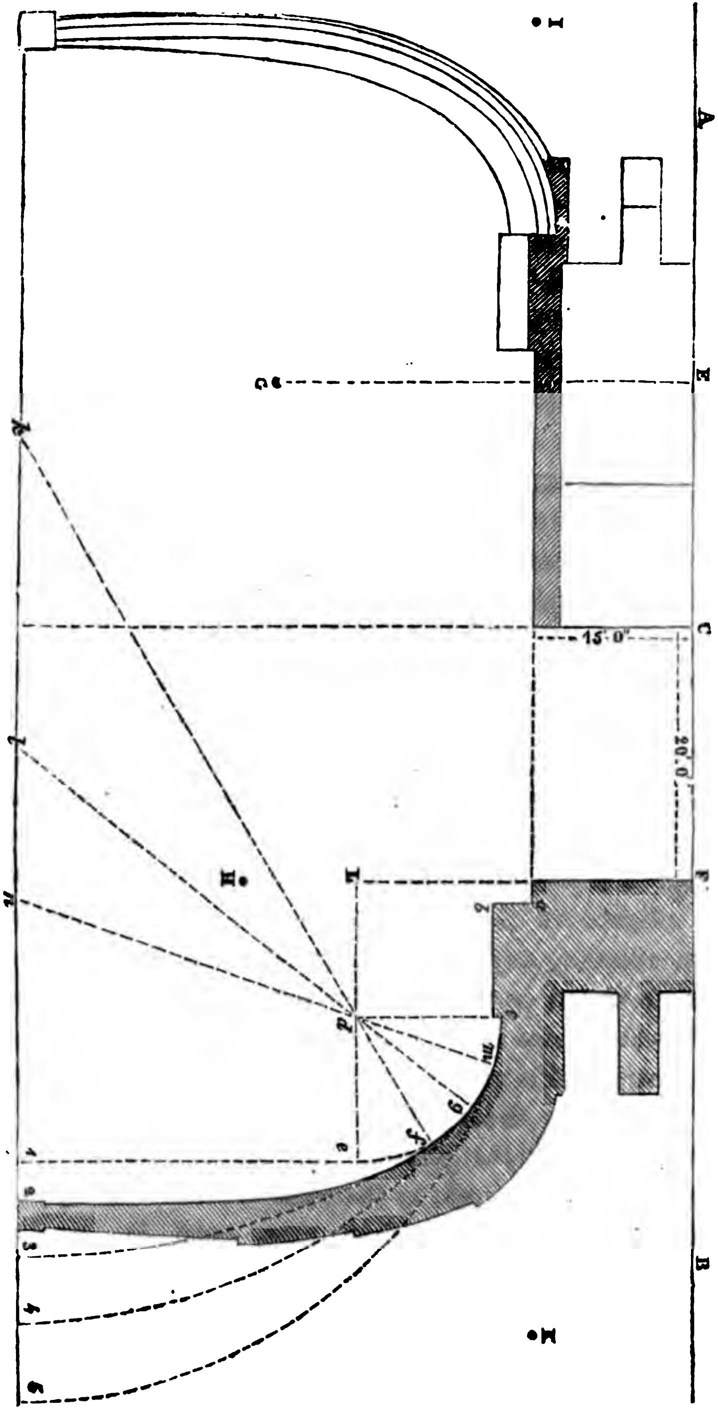
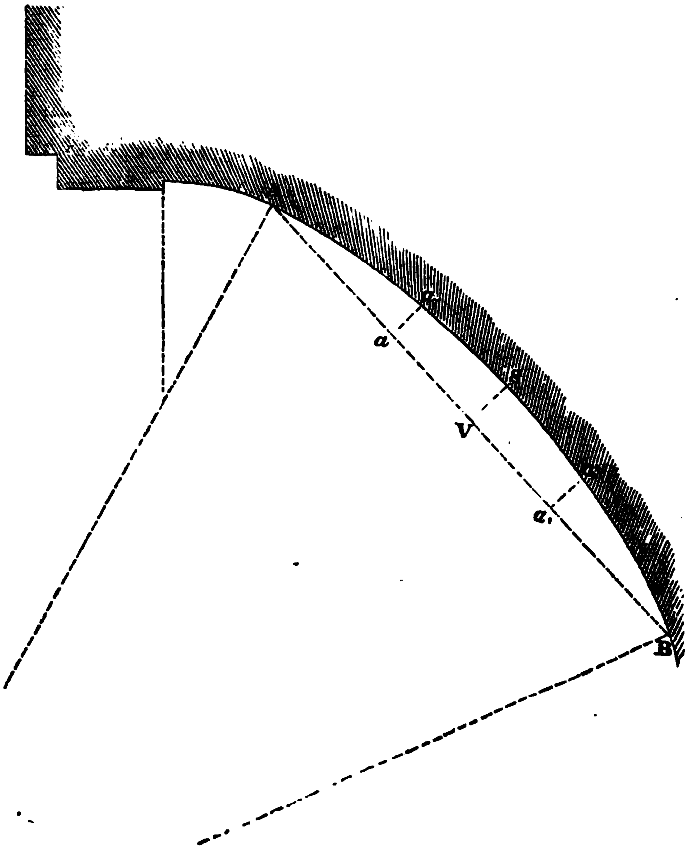


FIG. 5.

in the direction of H, a distance equal to the projection, plus the width of the face of pilaster, as at L, and from L a perpendicular equal to the depth of arch stone, plus also the width of the face of the pilaster. For number 1, pin a mason's line at centre *d*, and with the length *d c* describe the quadrant *c e*, from which produce the tangent *e* 1; this method is, however, only applicable where the length of the wing wall does not exceed 15 or 20 ft., because the straight line *e* 1 is by no means so well adapted to resist thrust as a curved wall. For number 2, describe the curve *c f* from the same centre, but make *c f* equal to *c d*, produce *f d* to *h*, making *f h* equal to three times *f d*, and from *h*, with a tight line, describe the curve *f i*, from any point of which you may produce a tangent to the site of the newel as *c f i* 2; for the reason above assigned, the straight line should never be longer than one-third or one-half of the total length, unless there be compulsive existing circumstances from locality. For number *c* 3, describe the curve again from centre *d*, and again make *c f* equal to *c d*, produce *f d* to *k*, which is at an equal distance from the face of the bridge at 3, and from *k* describe the arc *f* 3. For number *c* 4, still making *d* the first centre, and with same radius *d c*, describe the arc *c g*, making *c g* equal to two-thirds of *d c*, producing *g d* to *l* at the same distance from the face of the arch as 4, and from centre *l* describe the arc *g* 4. For number *c* 5, *c m* is but one-third of *c d*, the centre of second arc being produced being at *n* on *m d* produced; the two latter curves, from their wide sweep, are adapted to the wing walls of a viaduct rather than to a bridge. By adopting any of these methods, it is not to be supposed that the lines drawn on paper are to be transferred to the ground; it will be sufficient to give a few points on the curves, and to leave the centres well fixed for the reference of the masons, who will perfectly well know how to employ them. By assuming as a first radius a length equal to the width of the pilaster, the curvature is always adapted to the magnitude of the work, in the same manner as the pilaster.

An oblique direction of a river, road, canal, &c., may render it necessary to spread the wing wall to a considerable distance back into an embankment, when it will be much easier and fitter to set out the curve by ordinates found on the chord at equal distances from the middle of it, and for doing this there is a simple practical rule, when we have the length of radius and that of the chord. In Fig. 6, let B, the radius, be 80 ft., and C, the chord, 50 ft., for curve AB.

FIG. 6.



$$\sqrt{R - \left(\frac{C}{2}\right)^2} = \text{Cos.}$$

$$R - \text{Cos.} = \text{Vers. Sin.}$$

$$R^2 = 80^2 = 6400.$$

$$\left(\frac{C}{2}\right)^2 = 25^2 = 625.$$

$$\text{and } \sqrt{5775} = 76 = \text{Cos.}$$

$$(R)\ 80 - (\text{Cos.})\ 76 = \text{V.S., } 4.$$

V.S. equal to 4, will therefore give us one point on the curve as at S. We now want to obtain the length of the ordinates at given distances from the middle of the chord A B, that is, at given distances from the versed sine V.S.; say first 10 ft.

$$\begin{array}{lrl}
\text{From } R^2 & = & 6400 \\
\text{Deduct } Va^2 & = & \underline{100} \\
\text{From } \surd \text{ Diff. } 6300 & = & 79{\cdot}36 \text{ deduct the Cos. } 76. \\
 & & \underline{76{\cdot}} \\
 & & 3{\cdot}36 = a\,a.
\end{array}$$

3·36 is then equal to the ordinate *a a, a′ a′* at 10 ft. from V S, and by the same rule we may find any number of points in the curve, each calculation supplying 2 points at equal distances from the middle of the chord A B. When the foundations have been excavated and the masonry brought up to the level of the surface, a few points may be thus set off for the curve, and this precaution will remove all danger of an unsightly wing wall. It is very much to be hoped that the reader will now be persuaded of two things: how easy it is to avoid a series of unequal curves joined by short straight lines at all possible angles, and to obtain a wall of regular curvature throughout; and that in a viaduct, a bridge over a river or turnpike road, however simple the design and rough the materials, if the work be correctly set out with regard to curvature and inclination, it will always surpass in elegance the most finished design and highly-wrought materials, carried out and put together without attention to the particular points on which we have dwelt at a length which may appear fastidious, but nevertheless considered necessary from the very slovenly manner in which this work is too often done.

In setting out a bridge in a cutting, we proceed by similar means, finding the centre line of railway A B, and the centre line of the road, the intersection of which lines will of course be the centre of the bridge; from the centre line C D (Fig. 7), set out the faces of the abutments, each of which will be at a distance from the centre equal to the span, and make these lines of faces secure by stumps; the length of the wing walls will be regulated by the width of base of slopes, and will, in sidelong ground, be longer on one side than on the other, and before they can be accurately fixed, the edge of the slopes will require to be determined carefully; the two short pilasters terminating the wings should stand clear of the slopes. Bridges carrying roads over railways in sidelong ground, will require strict attention to the original or new inclination of the road. Fig. 8 shows a bridge under a level road; but suppose the gradient to be 1 in 30, and the distance from centre to centre of pilaster to be 36 ft., the top of the pilaster A will be 1·20 higher than pilaster B; any neglect on this

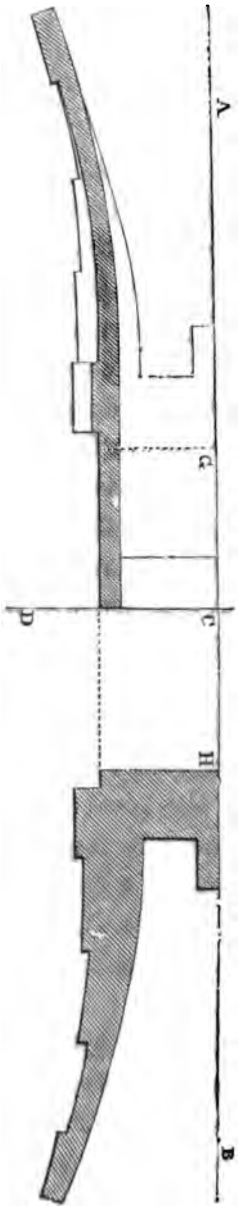


FIG. 7.

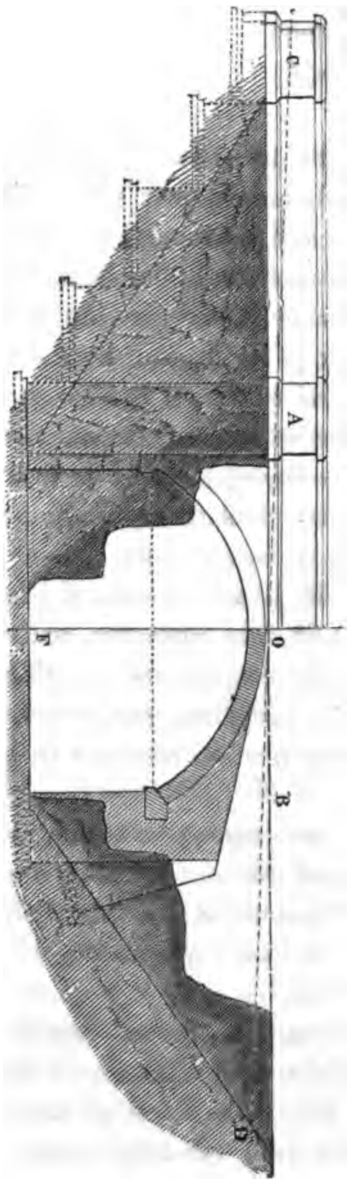


FIG. 8.

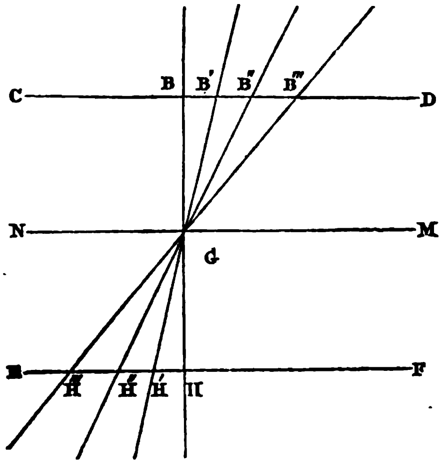
score would produce at least a crooked string course, and the metalling of the road over the bridge being higher up along the parapet at one end than at the other, besides the necessity of raising the parapet to obtain the four feet height above surface as required by law. In Fig. 8, let the dotted line C D represent the gradient, C, D, being the edges of slopes; by levelling from C to D we obtain the difference of levels.

C D =92·00
Diff. of levels=3·06.

From D to O=44 ft., and from O to B=18; 44−18=26; and difference of levels for 26 ft.=·86, and for 44 ft.=1·46; and 1·46−·86=·60 difference of level between crown of arch and pilaster B; but the crown of the arch is 20 ft. above railway formation, and 20−·60=19·40 for height of B pilaster, and for A 20+·60=20·60, and for the batter of pilaster at 1 in. per foot we shall have for B 19½ in., and for A 20½. In practice, having the gradient, we have but to deduct it from or add it to the height from formation to the crown of the arch, to ascertain the height of each pilaster. When about to set out a bridge in a cutting, the engineer will often find that he has to do this in very rough ground, as at Fig. 8; and as we should have to bone out over the very uneven surface C A F D, the eye would be very likely to get out of the lines A B, Fig. 7, and C D, Fig. 8; but if we fix C D correctly, and strain a line from A to D, we can find G H with due precision. This precaution will be found the more requisite in deep cuttings, where three arches often span the excavation, the centres of which, as well as the centres of the piers and abutments, must all be in one line, and an error, whatever it may be, will be a miserable distortion which must be ripped up at one side and patched upon the other. By using a plumb-line at about A or D, Fig. 8, we can easily make it coincide with that strained across the cutting, and thereby sight out the centres of abutments or piers.

The methods of setting out on the square being well understood, there will be no difficulty in readily apprehending the means employed to set out works on the skew, in which either the faces of abutments are at a given angle, and the faces of the arch parallel to the centre line of railway, as when the bridge carries the rails over a road or river, or the faces of the arch are at a given angle, and the abutments are parallel to the centre nick, as when the bridge carries the road over the railway; in either case, the dimensions on the square being given, these will always remain the same *on the square,* however the skew dimensions may vary, which will be with the angle of skew, as in Fig. 9, in

FIG. 9.



which let G B, G B', G B'', be the centre line of railway, when C D, E F, will be the lines of the faces of the arch; but if G H, G H' G H'', G H''' be the centre line of road, then will C D, E F, be the lines of the faces of the abutments; and G B, or G H, being the lengths on the square, G B', G B'', G B''', or G H', G H'', G H''', will be the lengths on the skew, and these latter lengths will become greater, as the sine of the angle G becomes less; the skew length, therefore, is in the inverse ratio of the sine of the angle of skew G M B''', &c., G N H''', &c.; we have therefore ready means of ascertaining the skew lengths. In Fig. 10, let B H be the span on the square, and let B' H' be the span on the skew, B' G M being the skew angle, the value of which has of course been ascertained by instrumental measurement, C D, E F, being the lines of the faces of the abutments. In the right angled triangle B G B',—

$$v\mathrm{G} : \mathrm{G}s :: \mathrm{BG} : \mathrm{GB}';$$

but $v\mathrm{G} = sc,$

and $sv = c\mathrm{G};$

and BG and $\mathrm{G}s$ are each = radius,

$\mathrm{GB}' =$ cosecant,

and *s c* is the sine, and *c* G is the cosine of the angle B′ G M of skew; hence we have:—

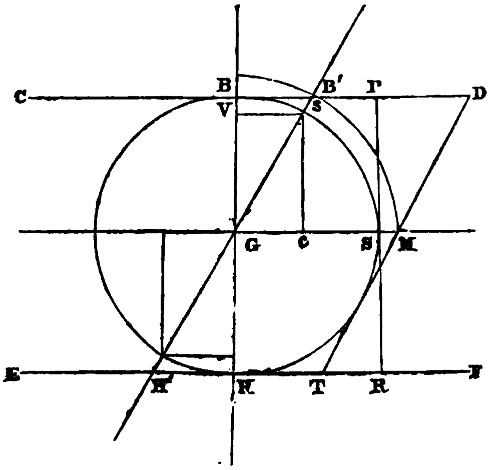
$$\text{sine of angle} : \text{radius} :: \text{radius} : \text{cosecant};$$

or,
$$\frac{\text{radius}^2}{\text{nat. sine}} = \text{cosecant};$$

or,
$$\frac{\text{span on the square}^2}{\text{natural sine}} = \text{half span on the skew.}$$

Having found the span on the skew, we have next to ascertain the width of abutments on the skew. Make B P, Fig. 10, the half width of abutment on the square, equal to the half span on the square, as, for instance, we should have in crossing a 30 ft. road, with 30 ft. for the width of formation; through P draw P R, parallel to B H, and with radius G B′ describe the arc B B′ M; through M draw D M T parallel to B′ H′. In parallelograms B G S P, D M G B′,

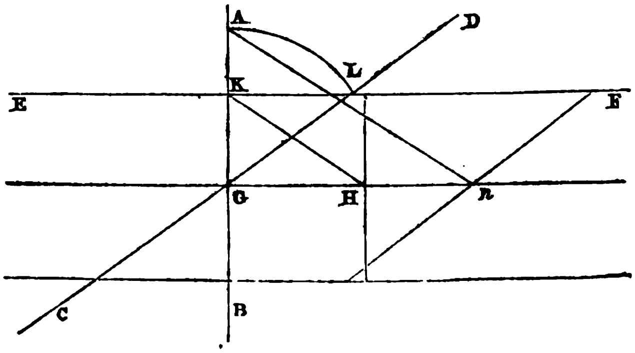
FIG. 10.



$$\text{B P} : \text{B G} :: \text{B′ D} : \text{B′ G};$$
$$\text{and B P} = \text{B G, then B′ D} = \text{B′ G};$$

and the half skew width of abutment D B′ is equal to the half skew span G B′, when, on the square, these dimensions are equal. In Fig. 11, let A B be the line on the square of the road, C D the line on the skew, and E F a line of one face of abutment; G H is the half width on the square, and K G the half span on the square; the length of

FIG. 11.



G L, the half skew span, we can obtain as above, Fig. 10, having the angle L G H. Make L M perpendicular to C D, and equal G H the half width on the square, and draw F B parallel to C D; join K H, make G A equal to G L, the half skew span, and make A n parallel to K H. In the right angled triangle A G n,—

$$KG : GH :: AG : Gn,$$

but,

$$AG = GL,$$

therefore,

$$KG : GH :: LG : Gn;$$

and in parallelogram G F,

$$Gn = LF;$$

then,

$$KG : GH \text{ or } KL :: LG : Gn \text{ or } LF;$$

but,

$$KG = \text{half square span},$$
$$KL = \text{half square width},$$

and,

$$GL = \text{half skew span},$$
$$LF = \text{half skew width};$$

therefore,

half square span : half square width : : half skew span : half skew width.

The following tables of half skew spans have been constructed to expedite these calculations; where the skew span is 30 ft., having the angle of skew, we have but to refer to the angle in the tables, and alongside of it will be found half the skew span; if the span on the square is more or less than 30 ft., it will be but a simple matter of proportion to find the corresponding skew span; as for a 40 ft. square span at an angle of 50°,00; the tabular number for 50°,00 is 19·58, then

$$15 : 19{\cdot}58 :: \frac{40}{2} : 26{\cdot}10;$$

and 26·10 × 2 = 52·20 for the skew pan. And for the skew width, with 20 ft. on the square width we have,

$$\frac{40}{2} : \frac{20}{2} :: 26{\cdot}10 : 13{\cdot}50.$$

or any length on the square × natural cosecant equal to skew length.

TABLE

Of Skew Lengths for 15 *feet on the Square; or radius*=15,
Cosecant=Tabular Number.

Angle of Skew.	Skew Length.	Angle of Skew.	Skew Length.	Angle of Skew.	Skew Length.
25°,00	35·49	28°,00	31·95	31°,00	29·12
10	35·27	10	31·78	10	28·98
20	35·05	20	31·61	20	28·84
30	34·84	30	31·43	30	28·70
40	34·63	40	31·27	40	28·57
50	34·42	50	31·10	50	28·44
26°,00	34·19	29°,00	30·94	32°,00	28·30
10	34·01	10	30·78	10	28·17
20	33·61	20	30·62	20	28·05
30	33·62	30	30·46	30	27·92
40	33·42	40	30·31	40	27·79
50	33·23	50	30·15	50	27·67
27°,00	33·04	30°,00	30·00	33°,00	27·54
10	32·85	10	29·85	10	27·42
20	32·67	20	29·70	20	27·30
30	32·48	30	29·55	30	27·18
40	32·30	40	29·41	40	27·06
50	32·13	50	29·26	50	26·94

TABLE

Of Skew Lengths for 15 *feet on the Square; or Radius*=15, *Cosecant=Tabular Number.*

Angle of Skew.	Skew Length.	Angle of Skew.	Skew Length.	Angle of Skew.	Skew Length.
34°,00	26·82	40°,00	23·33	49°,00	19·87
10	26·71	10	23·25	20	19·77
20	26·60	20	23·18	40	19·68
30	26·48	30	23·10		
40	26·37	40	23·02	50°,00	19·58
50	26·26	50	22·94	20	19·49
				40	19·39
35°,00	26·15	41°,00	22·86		
10	26·04	20	22·71	51°,00	19·30
20	25·94	40	22·56	20	19·21
30	25·84			40	19·12
40	25·73	42°,00	22·41		
50	25·62	20	22·27	52°,00	19·03
		40	22·13	20	18·95
36°,00	25·52			40	18·86
10	25·42	43°,00	21·99		
20	25·32	20	21·86	53°,00	18·78
30	25·22	40	21·72	20	18·70
40	25·12			40	18·62
59	25·02	44°,00	21·59		
		20	21·46	54°,00	18·54
37°,00	24·92	40	21·34	20	18·46
10	24·83			40	18·39
20	24·73	45°,00	21·21		
30	24·64	20	21·15	55°,00	18·31
40	24·55	40	20·97	20	18·20
50	24·46				
		46°,00	20·85	56°,00	18·09
38°,00	24·36	20	20·73	30	17·99
10	24·27	40	20·62		
20	24·18			57°,00	17·89
30	24·10	47°,00	20·51	30	17·78
40	24·01	20	20·40		
50	23·92	40	20·29	58°,00	17·69
				30	17·59
39°,00	23·83	48°,00	20·18		
10	23·75	20	20·08	59°,00	17·50
20	23·67	40	19·98	30	17·41
30	23·59				
40	23·50			60°,00	17·32
50	23·42			30	17·23

TABLE

Of Skew Lengths for 15 *feet on the square; or radius* = 15,
Cosecant = Tabular Number.

Angle of Skew.	Skew Length.	Angle of Skew.	Skew Length.	Angle of Skew.	Skew Length.
61°,00	17·15	70°,00	15·94	79°,00	15·28
30	17·07	30	15·91	30	15·25
62°,00	16·98	71°,00	15·85	80°,00	15·23
30	16·91	30	15·82		
				81°,00	15·19
63°,00	16·83	72°,00	15·76		
30	16·76	30	15·73	82°,00	15·15
64°,00	16·69	73°,00	15·68	83°,00	15·11
30	16·62	30	15·65		
				84°,00	15·08
65°,00	16·55	74°,00	15·60		
30	16·49	30	15·57	85°,00	15·06
66°,00	16·42	75°,00	15·53	86°,00	15·04
30	16·36	30	15·50		
				87°,00	15·03
67°,00	16·29	76°,00	15·46		
30	16·24	30	15·43	88°,00	15·02
68°,00	16·18	77°,00	15·39	89°,00	15·01
30	16·12	30	15·36		
69°,00	16·07	78°,00	15·33		
30	16·01	30	15·30		

We can now proceed to the practice of setting out works on the skew, and, as an example, we will take the bridge shown at Figs. 12 and 13, the skew angle of which is 55°,30, and the span on the square 36 ft. By the tables we obtain 18·20 for 15·00 on the square, at an angle of 55°,30′. We have then the following proportion :—

15 : 18 :: 18·20 : 21·84;

therefore 21·84 will be our half skew length. And for the half *skew* width we have the next proportion, without referring to the tables, although we have 15·00 for the half *square* width,

18 : 21·84 :: 15 : 18·20;

therefore 18·20 is the half skew width. And we have now our skew dimensions, 43·68 and 36·40. Now proceed to setting out on the skew centre lines A O A′, D O E, as shown at *S*, for setting out on the square. That is, from any point A, on one centre line, at *right angles* to A O, set out the *square* dimensions of 15′, on each side, as at B and C, and do the same thing from A′, at B′ and C′. On the centre line D E, at any points D and E, set out also at *right angles* the *square* dimensions of 18′, on each side of D E, as at F and G, and at F′ and G′; the intersection of these lines will give the points K, L, M, N, and K L, M N, will be the skew faces of the bridge, and K N, L M, will be the skew faces of the abutments. Now measure K L, and N M, and if each respectively give 43·68, or 43′, 8″, then D E, the centre of the road, will be at an angle of 55°,30″ with the centre line A A′, but not otherwise. The angle, or supposed angle of skew is generally measured from the plan, and the drawings made in the office, and the skew proportions given accordingly; unless the plan be very correct, there may be, and often is, a considerable difference between the angle of skew on the drawing and the angle on the ground—that is, the angle formed by the centre line of the railway, and the centre line of the road; this absurd discrepancy can always be obviated by measuring the skew angle on the ground before the drawing is commenced, as we have pointed out in the commencement of these pages. When, however, this discrepancy is found to occur, many persons shift the centre of the road E D, more or less one way or the other, until the right dimensions for K L, N M, are obtained, and a very slight deviation of D E will materially alter the angle; this is called "fitting" the work; and the reader may form a judgment for himself as to what it ought to be termed. By setting a box sextant to the given angle, and standing on the centre line A A′, and as near as possible to O on the centre line D E of the road, set out the angle, proceed as above with setting out the dimensions, and the matter is settled without any "fitting." Make fast the points C, B, C′, B′, F, G, F′, G′, and the faces of the bridge as well as the faces of the abutments may at any time be found, as well as their skew dimensions. In setting out skew bridges, attention should be given that the projection for the batter of the pilaster project not into the line of the face of the abutment. With regard to the wing walls, it may be mentioned that on level ground the four newels would include a rhomboid, of which the sides would be parallel to the sides K L M N, from which they would deviate as the ground, according to the rise or fall of the ground on one side or the other. In K R, M R′, the radius of the first circle is equal to the width of the pilaster, and the centre is on a line at right angles to the face of the bridge, and the chord of the circle is equal to the radius; the radius of the second arc is found by sighting the line from the end of the first arc through the centre on to the foot of the slope, or thereabouts. S, S′, are at a distance from the centre of the road equal to that of R, R′, from the same centre line, and the radius of L S, M S′ may be made equal to the chord. It will be perceived that by lengthening the first arc of K R, M R′, the terminal or newel may be brought nearer to the centre line D E; however these wings may be set out, every care must be taken that the newel be the most distant part of the wing wall from the centre line D E, or a very deforming effect will be produced. Skew bridges are expensive structures, not only from the increased dimensions of the body of the bridge, but also from the extension of the wing walls; where in heavy embankments, it is more economical to bring the wings into the body of the embankment, straight with the faces of the bridge, and terminate them at a distance equal to the depth of the embankment multiplied by 1½ or 2, and thus slope the embankment down to the pilaster, or a short dwarf wall may be constructed in line with the length of the abutment. The case above given being in embankment, where the ground would be clear, and free from encumbrances, would not offer the same obstacles as a skew bridge in a deep cutting, when the beginner would find it necessary and advisable to have recourse to the means pointed out at Figs. 12 and 13, in order to secure accuracy with regard to the centres, the dimensions, and the angles of the piers and abutments; but in this, as in all the former cases, the rules given, and methods pointed out in the foregoing pages, are in every sense so strictly practical, that the student, after due attention and thought bestowed on them, may be perfectly confident of success if he be careful, and if he be not misled by the "rough-and-ready school," and induced to have recourse to "fitting."

The methods of setting out viaducts on the square or on the skew are so analogous to the preceding cases, that it would be but a repetition to go into them, with the exception, however, of its being advisable to set out the lines of the centres of the arches as well as those of the faces of the piers and abutments, the stumps noting the lines for the arches being less liable to disturbance than those of the piers and abutments, even when kept at a distance from such heavy works as a viaduct; and it need not be added that equidistance and perfect parallelisms are essentials in setting out such a work. With regard to the levels, instructions will be found in the next article, which will treat of setting out a viaduct on a curve.

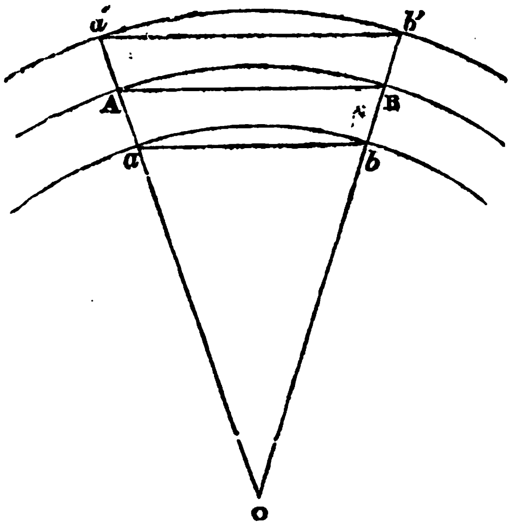
In setting out a viaduct on a curve, the first points to be obtained on the ground and on the centre line will be the centres of the arches; and the distances of these from each other will depend on the dimensions of the span and the thicknesses of the piers, and each of them must be set out on a curve of a given radius, which should be done by chords or by tangents. The subject of setting out curves having been already treated of, but little will be said on the subject here. By dividing the square of the distance by twice the radius, all in feet, we shall get the offset to the tangent as nearly as it can be set out. In Figs. 16 and 17, we have a rough sketch of a viaduct on a curve of 40 chains radius, the distance from centre to centre being 30 feet for the span, and 4′, 6″ for the thickness of each pier; 30′ + 4′,6″ = 34′,6″ will therefore be the distance from centre to centre, either of the arches, or of the piers; the square of 34·5 = 1190·25 and twice the radius = 5280; and offset = 0·225; let A, B, C, D, E, be these centres of arches on the curve A E. In Fig. 14 it will be seen that the arches are all square —that is, that the span of the face nearest to the centre of the curve is equal to the span of the outer face, each being of 30 feet; were it otherwise, we should have a conoidal arch, and this, of course, will greatly increase the inequality of the piers at each end. Now, in these cases, the difference between the arc and the chord is so small, that it may be disregarded, and we may assume the length of the chord for that of the arc, in calculating the difference between the lengths of A B, *a b*, *a′ b′*; let A O, B O be radii of 40 chains, or 2640 feet, *a* O, *b* O, radii 2640 − 15 = 2625 feet, and *a′* O, *b* O radii of 2640 + 15 =

2655 feet; that is, assuming the transverse axis of our arch as 30 feet, we have

$$\begin{aligned}&\text{A O or B O} : \text{A B} :: a\,\text{O or } b\,\text{O} : a\,b, \text{ that is,}\\ &2640 : 30 :: 2625 : 29{\cdot}82, \text{ or } 29'\ 10'' \text{ nearly,}\\ &\text{and } 30' - 29', 10'' = 2'';\end{aligned}$$

that is, that 2″ is the quantity which we shall have to deduct from the thickness of the piers on the inner side of the curve in order to make $a\,b$ = A B, that is 30 feet, half the difference, or 1′ being deducted from each side. By the same reasoning we have

FIG. 14.



$$\begin{aligned}&\text{A O} : \text{A B} :: a'\,\text{O} : a'\,b', \text{ that is,}\\ &2640 : 30 :: 2655 : 30{\cdot}17, \text{ or } 30', 2'';\end{aligned}$$

we have therefore 2″ again for the difference, half of which is to be added to each side on the pier at the end on the outer curve.

Moreover we have

$$2640 : 4{\cdot}50 :: 26{\cdot}25 : 4{\cdot}47;$$

and as

$$2640 : 4{\cdot}50 :: 26{\cdot}55 : 4{\cdot}53 \text{ nearly,}$$

therefore at the end nearest the centre, the thickness of the pier will be

$$4{\cdot}47 - {\cdot}18 = 4{\cdot}29,$$

on the centre line 4·50 as given, and at the end of the pier, on the outer curve, or the farthest from the centre of the circle, we shall have

$$4{\cdot}53 + {\cdot}17 = 4{\cdot}70.$$

The above calculations have only been gone into to show what the dimensions of the piers will be, as also to explain more fully the principles on which such a work as a viaduct on a curve is set out. With regard to the practice, having found the centres A, B, C, D, E, Fig. 16, set out lines perfectly at right angles to the common chord, shown at A, as at *a* A *b*, *a′* B *b′*, *a″* C *b″*, *a‴* D *b‴*, &c., producing them sufficiently out of the works that the stumps, securely driven in, may be easily found again; and let it be remembered, that if these centre lines of arches are lost by the stumps being pulled up, the work will require fresh setting out, when the ground may not be in a very convenient state for doing so. Having now found the centre lines of the arches, measure off from A towards *a*, and towards *b*, half the width of the viaduct, say 15 feet, as at F and G; also from A set out on the centre line, half the span as at 1 and 2, and from 1 and 2 on each side of the centre line, and at right angles to the *common* chord, set out again half the width of the viaduct, 15 feet, as at H, K, L, M, when H F and F L will each measure half the span, as will also K G and M G, if the dimensions have been correctly set out. Now from centre B proceed in the same manner, as first on *a′* B *b′*, on which set out N and O; then from B on the centre line, set off 15 feet, at B 3 and B 4, next 3 P and 3 Q, also 4 R and 4 S; check as before, when P N, R N, Q O, S O, will each measure half the span. And now measure the two ends of the piers, when L P should measure 4·70, and M Q 4·47; treat the arches C, D, E, &c. in the same manner, when the position and dimensions of all the piers and abutments will be set out, and, consequently, the uniform span of the arches; in setting out in deep water, staging, and if necessary, boats or rafts are provided. With regard to batter, this is generally a matter of levels, when the batter reaches to the foot of the piers; in Fig. 17, the sides of the piers are plumb for a certain depth from the surface; but suppose the batter to be ½ in. per foot, at depth 47·25 we shall have for batter 47·25 − 10′·00 for rise of arch, and springer = 37·25 ÷ 4 = 9¾″, near enough for practice for batter on each side; and at 59·15, we shall have a similar calculation, due attention being given in every case to take the gradient into calculation, and to operate only on the depth *below the springer*. Having carefully taken the levels over *the site of the piers*, checking on all B M s, the heights to formation are easily obtained, from which deducting surface height from datum, and from the remainder the rise of the arch and depth of springer, carefully including the depth of the level of springer, as at Fig. 21, we obtain the height of the pier. Care is required in doing this, as it is the only means of obtaining a true and uniform batter, and avoiding a distorted line which always shows itself strongly in the arrises of the piers.

In the curves which we usually set out in railway works, the versed sine bears but a small proportion to the length of chord; but for reservoirs and other engineering works, we may have to set out curves where the versed sine may bear a much greater proportion to the chord, as in Fig. 18, where let A B be the chord, and V S the versed sine; set out A C from A, and B D from B, each equal to V S, and at right angles to the chord A B; also from A, set out A E, at right angles to A S; and from B, B F, at right angles to B S; through C, S, D, set out E F at right angles to S V; divide A B into any number of equal parts, as at 1, 2, 3, 4, &c., and picket them; divide E F into an *equal number* of equal parts, as at 1′, 2′, 3′, 4′, &c., and plant rods at each; and now divide A C, and B D, each into an equal number of equal parts, as at G, H, I, K, &c., G′, H′, I, K′, &c., and stump these also. Now standing at 1, bone out 11′, and an assistant standing at G, let him bone out G S; intersection *a* will be a point on the curve; repeat the same at 2, and at H, when *b* will be a second point on the curve; again at 3, and at I, and *c* will be a third point, until we have also *d, e, f, g, h, k, l, m, n, o, p*. Of course A B may be divided into any number of feet, from V to B, and V A. This method only applies where A B and V S are accessible lines, but where this is the case, and where a considerable number of points on the curve are required, and A B only 200 or 300 yards, it is an expeditious and accurate way of getting the curve.

In setting out culverts in sidelong ground, attention must be given to the length required for the arch; in general it will be sufficient to set out the foot of the slope with accuracy, and multiplying the total height of the culvert by the ratio of slope, set back the result for the end of the arch, as in Fig. 19, where the base of slope is 53·50; height of culvert, 8·50, and this by 1½ is equal to 12·75, when we have to set back 12′,9″ from the foot of the slope. Cases, however, occur, where this is not sufficient. In Fig. 19, the height of embankment on the nick is 23 feet, and the height of culvert 8′,6″; this from 23 feet leaves 14·6, for which height the base of the embankment would be 36′,9″, and to this add the fall per foot multiplied by the ratio of the slope; of course this last quantity would have to be deducted on the higher side of the ground.

In setting out the bevels of springers to segmental arches, the following proportions are to be observed; in Fig. 20.

$$OR : OS :: RT : RV;$$

that is,

as the radius is to half the span, so is the depth of arch stone to RV; and

$$OS : RS :: RV : TV:$$

that is,

as half the span is to the radius minus the rise of the arch, so is RV to TV the rise of bevel.

For the extrados thickness of arch stones,

$$OR : Ra :: OT : Tb;$$

that is,

as the radius for the intrados is to the thickness of arch stones at the intrados, so is the same radius plus RT, or the depth of the arch stone, to TB.

To set out the slope of a wing wall under the coping, on the masonry, has been as yet omitted; to do which we may use the following simple means:—in Fig. 15, let A be the point in the pilaster and abutment where the top of the wing wall runs in, and let B be the top of the newel; strain a line between A and B, and fasten it down at those points; set out C square with A and B on the top of the embankment, and make C *level* with A, the top of the pilaster; by stretching a line from C to any point on the line A B, we get the required level of the wing wall under the coping, wherever the second line touches the top of the masonry, each of the lines being in the inclined plane A B C.

FIG. 15.

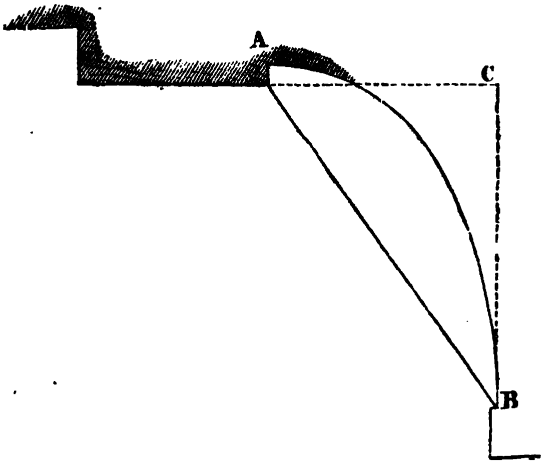


Fig. 12.

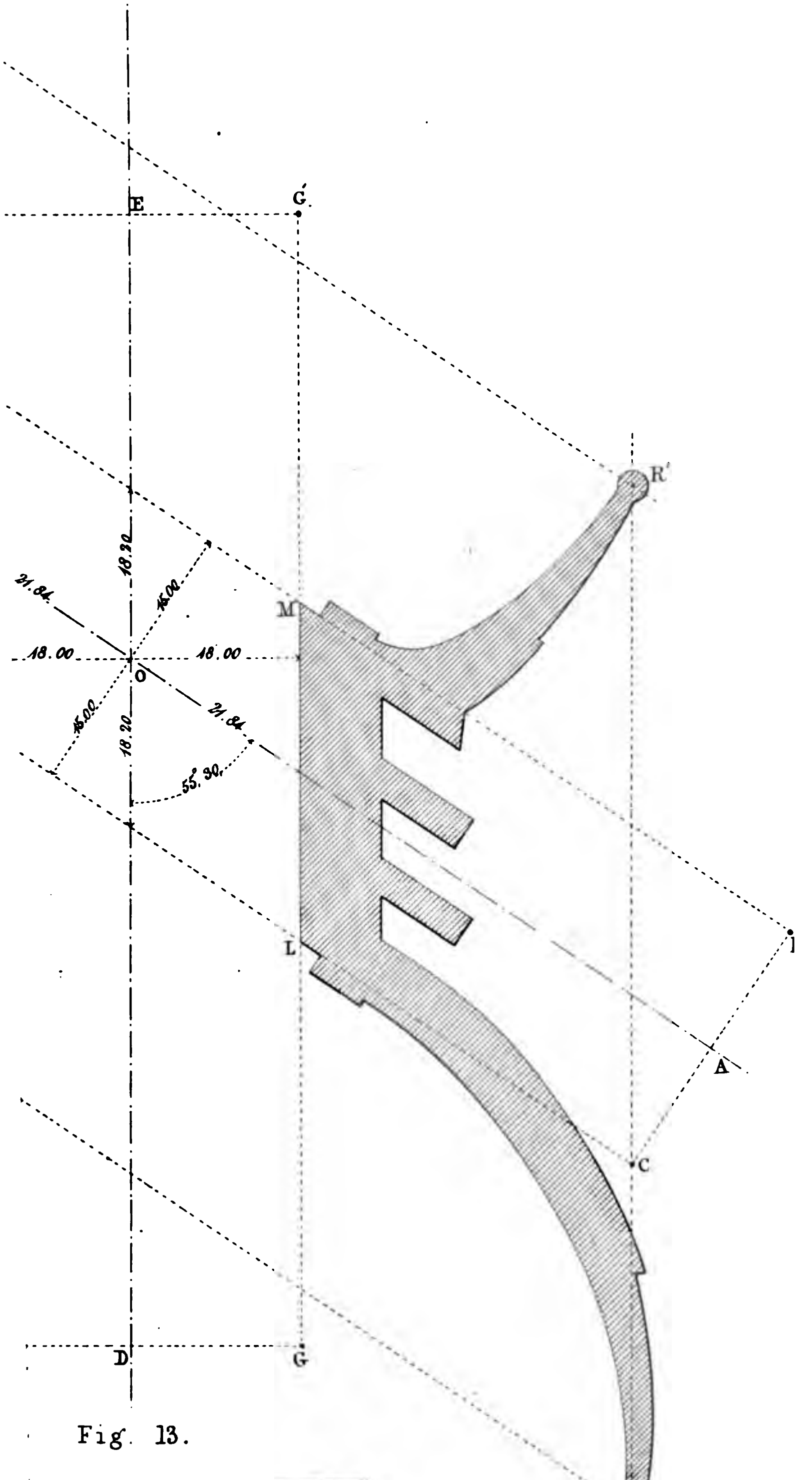

E
G'
R'
M
21.84
18.20
15.00
18.00
18.00
O
15.00
18.20
21.84
55° 30'
L
A
C
D
G
S

Fig. 13.

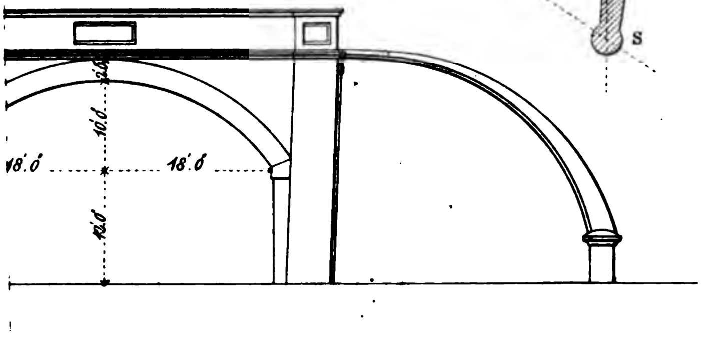

2.0
10.0
18.0
18.0
12.0

Fig. 16.

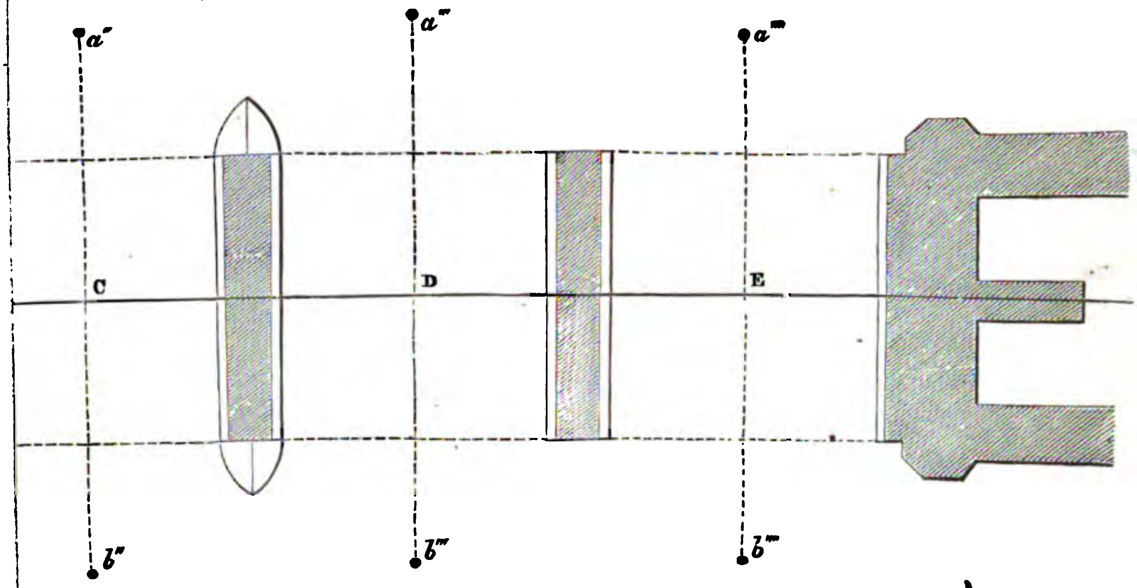


Fig. 17.

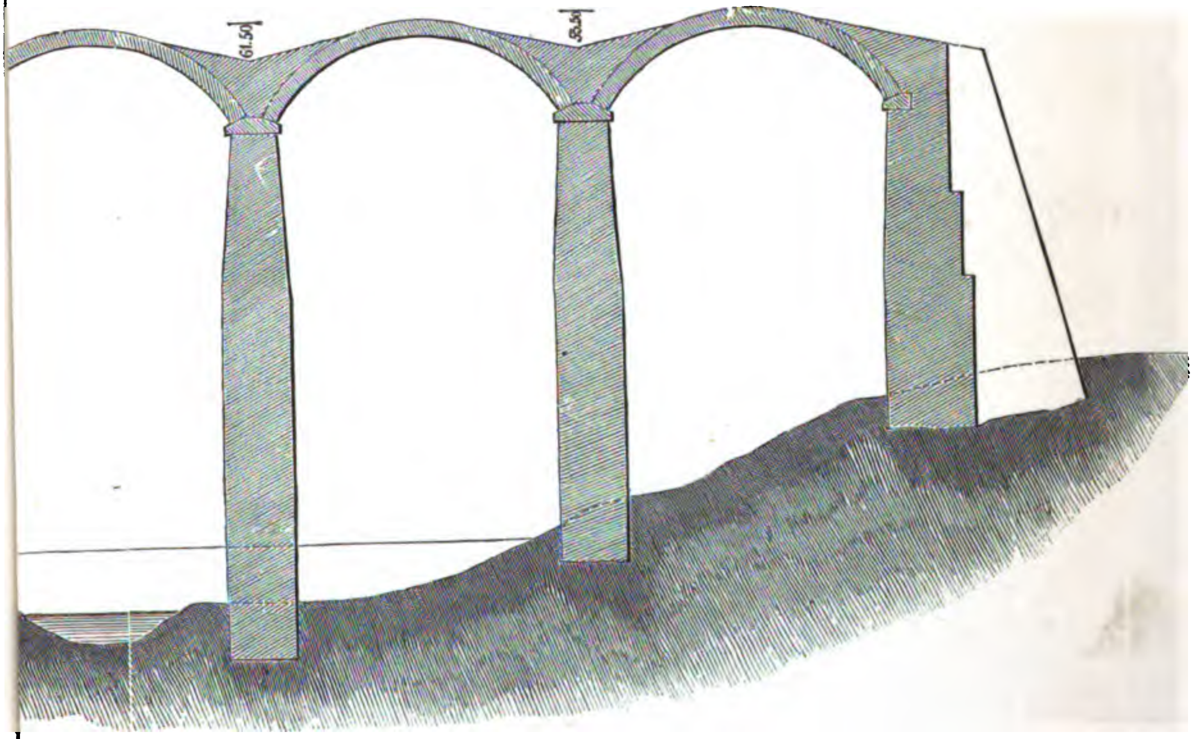


FIG. 18.

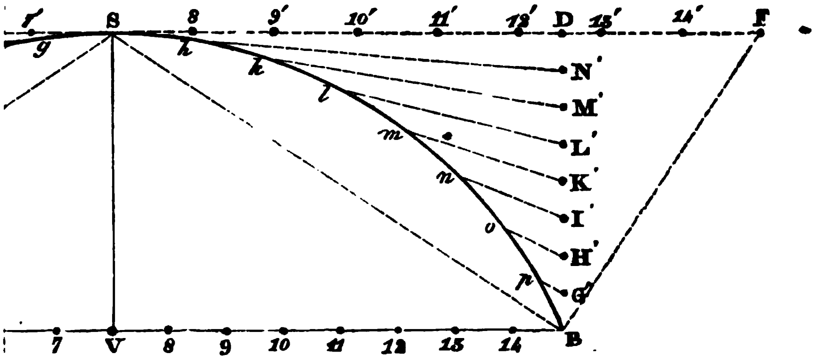
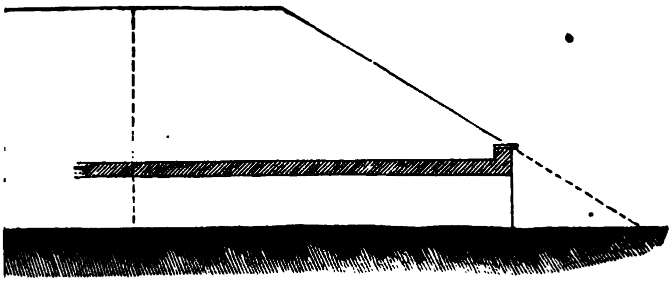
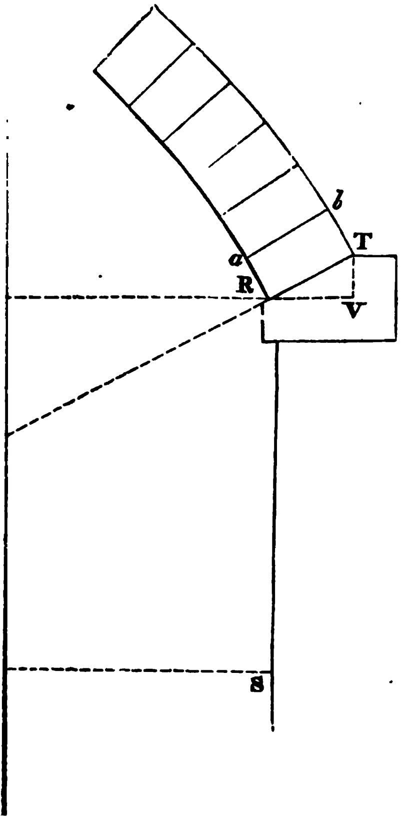


FIG. 19.



20.



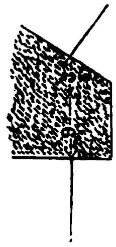


FIG. 21.

CHAPTER VI.

EARTHWORK.

Amongst the many important works connected with the construction of a railway, it is doubtful whether any require more attention, experience, and knowledge than the earthworks of deep excavations, and the formation of heavy embankments. Where, to the unaccustomed eye, all appears confusion, in a well-regulated cutting the numerous gangs of excavators move in a confined space with the regularity of well-ordered machinery; and those having charge of a heavy work of this description will speedily experience the paramount necessity of strict attention to a correct division of labour, and a serious investigation of the most applicable methods to particular circumstances, as well as a suitable disposition of the means employed in the shape of "the plant," a descriptive account of which to a reader can produce little more than a chaos of confused fancies; one hour's attention to the proceedings and details of work in an excavation would be far more beneficial. There are, however, a few subjects connected with cases of common occurrence, of which an investigation may be useful to the *inexperienced*, and which will be attempted in this chapter.

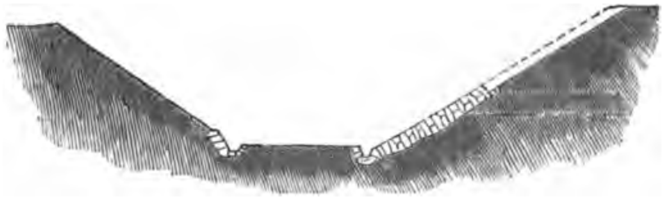
The first operation, as soon as the widths have been set out, is the erection of the fencing, consisting generally of "posts, railing, and prickposts," the latter planted midway between the posts, and well nailed to the rails; the assistant Engineer will examine this work as soon as set up, and see that the posts are firmly fixed and sufficiently deep in the ground; also that the ends of the rails go right through the posts, that they are fitted, and the whole firm and tight; where this is not the case, the fencing is likely to be levelled to the ground by the "soil" thrown up against it.

In "stripping the soil" from the top of cuttings and seats of embankments, it is customary to take it off "spade deep;" it should be piled up along the "Bench," between the intended edge of the cutting and the railings, the grass being laid lowermost; where the bench is 10 feet wide, a path of about 1′ 6″ should be left along the top of the cutting for the traffic of the men, and by which also the weight of the soil does not bear immediately on the edge of the cutting.

Where the top of the cutting is flat, and particularly of a wet nature, as soon as the soil is taken off, trenches about 1 foot deep should be cut along the lowermost levels, for the purpose of draining off the water to the nearest watercourses; this will be found to dry the earth to be excavated, and render it better fitted for the formation of embankments.

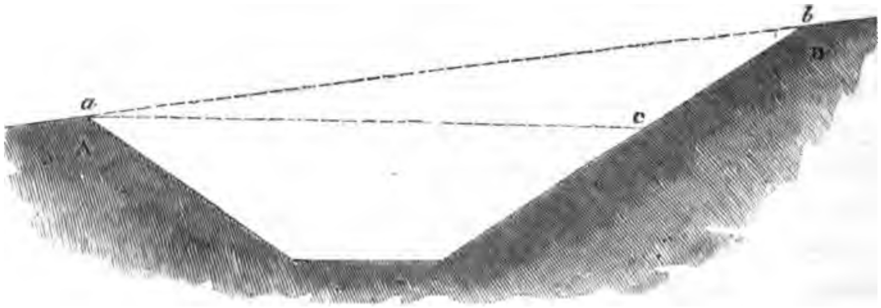
The determination of slopes for earthwork is one of the most uncertain subjects the Engineer has to contend with, if he be anxious to reduce as much as possible the quantity of excavation, and that of land to be purchased, both formidable items of expense; but this reduction is attended with one great danger—namely, a "slip," which will often for a considerable length occasion a double and treble quantity of excavation, and the purchase of a corresponding quantity of land, which in these cases, from the avaricious rapacity of many landowners, becomes enhanced to four and five times its real value; the greatest caution, and the most careful investigation of the nature of the earth to be excavated, as far as this can be done, and also of the local circumstances which may increase or diminish the danger of a slip, become absolutely necessary. The slopes of cuttings in gravel will stand at almost any depth at 1½ to 1, and at depths of 10 feet and 15 feet at 1 to 1; chalk is more uncertain; in solid rocky masses it will stand perpendicular; friable, it may require slopes of 1 to 1; shale will stand at ½ to 1, if the stratification be horizontal and dry, but when wet and soapy, there will be great uncertainty; clay, however, is by far the most uncertain and treacherous earth to be met with in excavations; we have known it for many months to stand perpendicular for a depth of 40 feet, and suddenly slip off, determining a slope of 3 to 1; there is no doubt that one of the most dangerous practices of excavators is to allow a gullet of this depth and nature to stand for a great length of time without lightening the sides, nor should it under any circumstance be allowed. A thin bed of clay will very often occasion the slip of material of a better nature, but this may be walled up, and, where stone is abundant, it should be done, immediately there is any sign of motion making itself perceptible by cracks at the top of the cutting; there should be no hesitation in such a case, nor fear of the word "expense," where 20*l.* or 30*l.* may save 10 or 100 times the amount. A dry rubble wall, built of the largest stone conveniently attainable, will be found the best remedy, both as regards efficiency and economy; *see* Fig. 2. When a slip has once fully declared itself, there is little left but to submit to the circumstance, and to form the slope to the extent determined by the slip, except, indeed, in the case of buildings, or gardens, &c., when we must have recourse to retaining walls and long counterforts with a good system of drainage, which will always be found indispensable; so much so, that no good results can be expected from the best-built and thickest walls without it.

FIG. 2.



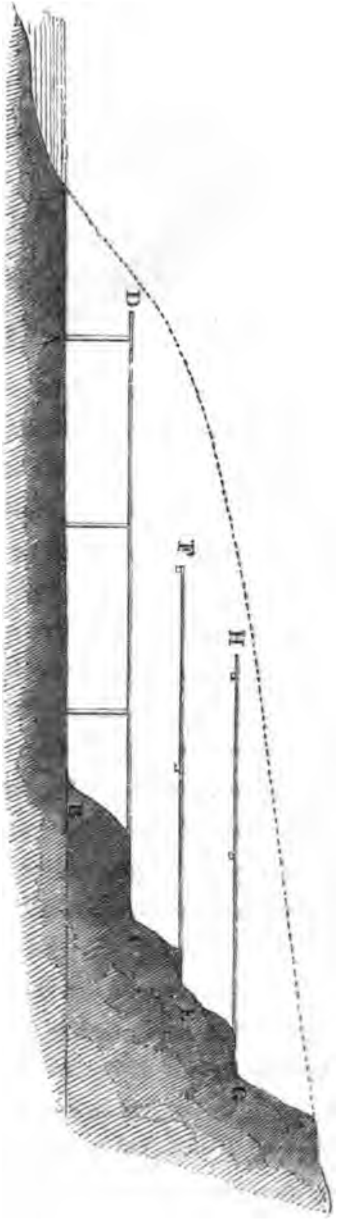
It is more particularly in cuttings in sidelong ground that slips occur, and this always on the higher side; and we are led by this circumstance to think, that in excavations where the nature of the earth is unfavourable to the stability of the usual slope, 1½ to 1, it would be far better to make the latter steeper on one side, and depress it in a corresponding ratio on the other; the earthwork would be increased on one side, nor would the diminution on the other counterbalance this excess, but it would not be so great. In Fig. 3, the weight on slope A is diminished, in proportion to the side of the angle *b a c*, whilst on side B, it is increased in that proportion, the friction or source of support being also decreased on the side B, in the same proportion, on account of the slip, and increased at side A; independently of this, the lower side, A, is far more efficiently drained. This would assuredly lead us to the opinion, that the batters should not be alike under such unlike circumstances; nevertheless, it is usual to make the slopes alike. Notwithstanding this practice, we should not hesitate in making an experiment contrary to it, in cases where slips might be anticipated, and in cuttings of blue clay, and on sidelong ground, at a depth of 25 feet, and even less, they may be constantly expected at slopes at 1½ to 1. Rank and reedy vegetation is a pretty sure sign of a future slip; caution may therefore be used accordingly; surface draining will always be found the most efficient preventive to slips, which too often occur from this precaution being neglected; and it cannot be too carefully remembered, that against this very serious evil too much attention cannot be directed. In mountainous districts, the side ditch at the top of a cutting and foot of an embankment requires particular attention, when heavy floods rushing down the side of a hill will, if not intercepted by a capacious ditch, very soon wash away and destroy the exterior surface of the slope of a cutting, and tear up the foot of an embankment; but of this latter we will speak further on. Attention should also be given to the bottom of the ditch at the top of an excavation being at a lower level than the edge of a cutting. Another earth, or rather mixture of earths, requiring great precautions, is a diluvium, consisting of large boulders of rocks, clay, sand, &c., where the rock being without bedding, falls in as soon as laid bare, and by its great weight determines the fall of large masses; but against this there is no remedy. One of the most fruitful sources of slips, after the completion of works, as well as during construction, is from springs and soaks rising in the sides of a cutting; these, though acting more

FIG. 3.



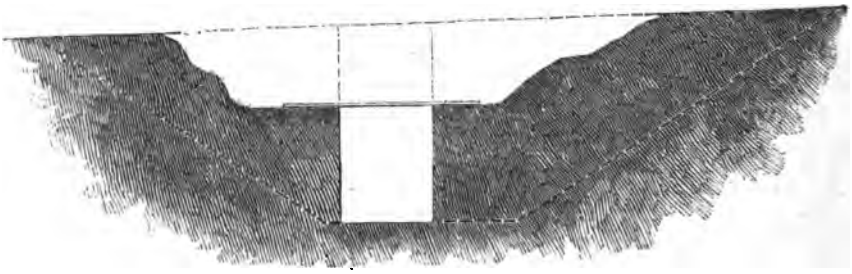
slowly, are as certain agents of destruction as gunpowder. The water springing from these must be carried off during the excavation of the cutting, by means of wooden troughs, where more simple means are ineffectual; and, as permanent work, a good brick or stone drain must be run down the slope into the side drain at the foot of the cutting, and the efficiency of the latter will depend upon their soundness and capacity.

FIG. 4.



At the commencement of an excavation, the earth is removed by means of wheelbarrows to the seat of the embankment; but as soon as a gullet is formed, wagons are introduced, and rails are laid to facilitate the traffic; this gullet is about 15 feet wide, and the sides kept perpendicular, and as the depth of the cutting increases, the number of excavators is increased by making fresh "lifts." The sketch, Fig. 4, will perhaps assist in explaining; the empty wagons would stand along plane A B; those nearest to B would be filled by excavators working against the face B; the wagons nearest to A would be filled from the face C, the earth there excavated being wheeled in barrows along planks C D, and tipped into the wagons, and the wagons midway between A and B would be filled from E, from which the stuff would be wheeled along planks E F; in cuttings of 30 feet deep, we have seen excavators thus working four lifts, six excavators being at work on each face. The excavations on the sides of the gullet should be carried on at the same time—as soon, at least, as the gullet has made some progress, by similar means, and in a like way; that is, by gangs of men working above each other, wheeling along planks, and tipping into the wagons below, Fig. 5; the planks are supported on uprights, or on transverse baulks.

Fig. 5.

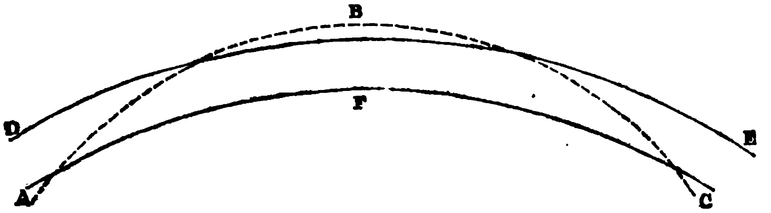


It is by having as great a number as possible of excavators, but not enough to embarrass each other, with a proportionate number of wheelers, and relays of wheelers, drivers, horses, and men at the tip, that a cutting and embankment progress rapidly and satisfactorily; and it is in so ordering the proportions of men to each task, as well as the disposition of the materials forming "the plant," that none shall be for a moment idle, and that a free passage for the going and coming of the wheelers be at all times kept open, that knowledge and experience on this subject are displayed, and which can only be acquired by strict attention and experience. In order to relieve the horses from as much labour as possible, it is proper to give a greater inclination to the plane A B, Fig. 4, as the excavation and tipping advance, consequently, receding from each other, in order that, by the sole effect of gravity, the wagons may obtain the greatest possible run towards the tip; it will therefore at once be seen how much, even at this stage of the work, depends on a good laying and maintenance of the way; for if it be not kept in tolerable order, the wagons are continually getting off the rails, thereby occasioning a delay of serious import by delaying those behind it, until it be got into its place again, to do which, with a heavy load of earth, will take a considerable time. These remarks hold in all earthworks, either of railways, docks, harbours, &c. By paying due notice to these details, the Engineer, when inspecting the works, may judge pretty readily of the progress of the works.

With regard to the proportions of men required for "getting, filling, and wheeling," or of wagons, horses, and drivers, local circumstances can be the only guides; if we were to ascertain these proportions by $\frac{t}{t'}$, where t represents the time of "getting," that is, excavating, and t' the time of filling or loading, the proportions would so far be ascertained; but our excavators, besides picking, have recourse to what is termed "falling"—that is, breaking down a mass of one or two cubic yards often in a few minutes, by driving in short piles shod with iron, and pouring in water until a mass falls to the bottom of the lift, where it is broken up by picks, and the quantities thus fallen are continually increasing as the depth of the face deepens; this would necessitate continued fresh calculations, which would be but indifferent approximations; the number required of wheelers would be under the same unfavourable circumstances for calculation; it is therefore usual to judge of the proportions required on the spot as the work proceeds, which will, in this case, be found better adapted to practice than calculations made without sufficient data.

Where the centre line of an excavation is straight, there is little risk of the excavators cutting into, and thereby irremediably deteriorating the slopes of a cutting; first, because they know very nearly (to a few inches) where their centres are, and by multiplying the depth by the ratio of slope they can keep themselves straight, the more easily that they seldom work to their formation depth until the levels are given, because if they go too deep, not only they are minus in pay the extra quantity of excavation, but they have also, at their own cost, to replace ballast to fill up the extra depth. We would not, however, recommend an Engineer to depend too much on this, as excavators will often make strange blunders. We have known an old excavator, of fifteen years' standing, with three correct levels within a chain on each side of him, make an error of 3 feet; we would, therefore, recommend the assistant Engineer to keep a close look-out after these matters under any circumstance. Where the centre of an excavation is a curve, in order to ease the running of the wagons, it is customary to flatten the curve of the gullet as much as possible, and here the excavators are by no means unlikely to cut into the slopes, unless their centres are often given to them. In Fig. 6, let A B C be the nick; the excavators will flatten the curve of the gullet by running it at D E, and they are

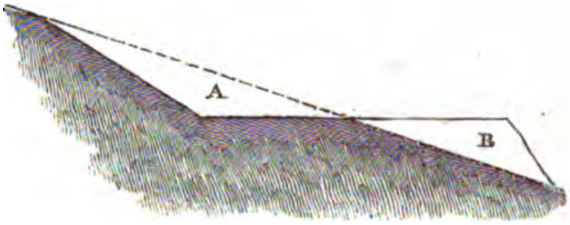
Fig. 6.



consequently likely to cut into the slopes at A, F, C, unless the ganger is made aware of the position of his centres. At the same time, continual setting out of the curves where they are numerous is a work absorbing much time; we, therefore, recommend the practice of driving in stumps at each side of the curve stumps, after their being once found in the gullet, and noting the distances; these side stumps, being less liable to disturbance than the centre stumps, serve as guides to set off the centre line sufficiently near, until the time comes when the centres are required for the permanent way.

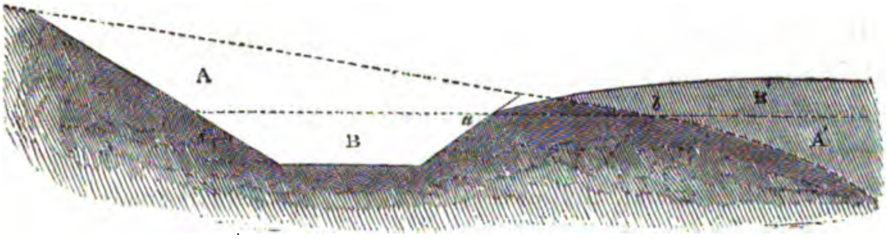
It is by no means an uncommon occurrence that a cutting is so situated, either that the length of lead is too great, or, which is the same thing, too expensive; or a heavy cutting may be what is termed locked up—that is, there may be no road to lead the excavated earth to a tip, either from other cuttings being between it and the nearest embankment, or a viaduct or bridge may require to be built before a road can be got ready for the wagons to run. Under these circumstances, the whole, or a part, must be "led to spoil," that is, some hollow must be filled up, or some bank formed, upon land unconnected with the railway; a hollow to be filled up would, of course, be preferred, both for the greater convenience of tipping, as well as because it would afterwards be easier to lay the soil on it, and "make it into land;" when it is necessary to lead excavation to spoil, it is customary to rent the land for a term, two or three years, or to pay compensation for damages. Fig. 7 shows the easiest spoil bank to be formed, the dotted line representing the original surface, the earth having merely to be excavated from A and tipped at B; a large number of men may excavate on the face, and there may be a corresponding number of tips. Fig. 7 represents what would be a more complicated and expensive

FIG. 7.



case. The upper dotted line as before represents the original surface; at every 15 or 20 yards along the lower ridge of the cutting gullets are cut a few feet deep, as shown by the lower dots, *a b*, through which

FIG. 8.



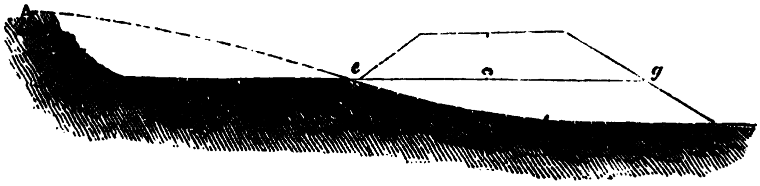
wagons in this case may at first be employed, to lead off the portion marked A in excavation and A′ in spoil; the lower portion B of the excavation must be raised by barrows wheeled upon planks and deposited at B′ on A′. Excess of cutting may also be disposed of by widening the nearest embankment—that is, instead of making it 30 at top, make it 40.

Another common occurrence is to find an intended embankment placed in a position very similar to that of the above-mentioned cutting, that is, either there may be no excavation to form the embankment with, or the embankment may be locked up, or the material may be too distant, and it may be cheaper to purchase land for "side cutting," from the excavation of which the embankment may be formed entirely or in part. The Fig. 7 may be a case of this kind, putting B for the embankment, and A for side-cutting; when land is purchased or rented for spoil banks or side-cutting, the soil should be stripped off and carefully preserved, as it is ultimately to be relaid on the top of the spoil bank, or bottom of the side-cutting; in either of these cases, as indeed in all other matters, due judgment should, of course, be exercised as to what excavation should go to spoil, or what embankment should be formed from side-cutting; also as to the side of either of these auxiliary resources, but, *cæteris paribus*, the nearest will be the best.

The next most important feature in earthworks, and intimately connected with the last, is the formation of embankments; and when these are of great depth, and to be constructed with unfavourable materials, and under unpropitious circumstances, they require the serious attention of the engineer, and this not only as regards the embankments themselves, but also the masonry and brickwork on the line, often, as well as other works and buildings, at a considerable distance. The best materials for the formation of embankments are gravel and sand, both from the facilities they offer for drainage, and their more rapid final consolidation; *soft* shaly earths are unfavourable, but if hard and dry they form good embankments, and settle well at slopes of 1 to 1; vegetable earths, or what is termed soil, must be entirely rejected for the embankment, from their being so easily converted into soft mud; landowners, however, are always ready to carry these away, but care should be taken to preserve a fully sufficient quantity for soiling slopes, as when a good depth of soil has once produced a strong vegetation, it forms one of the best safeguards to slopes. Clays mixed with a quantity of stones are by no means a bad material, and, if dry, will form a sound embankment, though rather long in consolidating; wet clay is as bad if not worse than peat; it should never be allowed to be used, under any circumstance whatever; a few wagons of wet clay tipped in a deep embankment will do more mischief by its slipping and saturating all other materials laid on it, than one, or even two thousand of good stuff will rectify, besides becoming for many years a continual source of settlement, and perhaps of danger on that portion of the line. Where the less favourable materials must be employed for forming embankments, it is as well to make an exception to the general rule, of forming at once an embankment to its full height and width, and to leave a few feet in height to be raised up with drier materials, *if conveniently at hand;* isolated masses of this description are often found in excavations otherwise of very inferior materials, which may be successfully employed for this purpose, after having, however, the positive assurance that enough remains for ballast. This is, perhaps, all that we can generally effect, as regards selection of material, without involving a company into great expense, because the embankment must always be formed of the materials from the nearest cutting.

With regard to the precautions necessary to be observed in the formation of embankments, we must be guided by a careful judgment of causes and effects, which are necessarily continually varying with local circumstances; there are, however, a few cases of common occurrence, of which it may not be unserviceable to say a few words. To obtain a thorough consolidation, and a complete unison of the mass, as well as to secure, as nearly as it can be done, uniformity and regularity of inclination in the side slopes, an embankment should, from the first, be formed to its full width and height, care being taken to make allowance for shrinkage and settlement from the gradual combination of particles into a solid mass; of this we have already spoken above. Another case may be the same as, or analogous to, the following:—We have an embankment to form which will require 80,000 cubic yards, and this embankment is at the tail of a cutting containing only 50,000; moreover, the next excavation beyond is required for other embankments, or it is at a great distance, which would make the lead a considerable item of expense, or it may be locked up from the embankment we are now anxious to form; it is evident we must get 30,300 cubic yards from side-cutting; if we are on sidelong ground, we can easily obtain this extra quantity from the upper side of the hill, and this very rapidly, as we can employ a considerable number of men upon a broad face. Let Fig. 9 represent a case of this kind, A B being

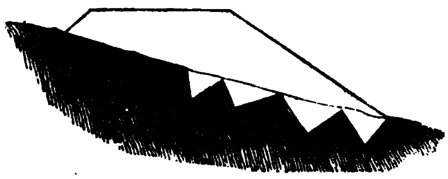
FIG. 9.



the original surface. Set out the foot of the slope towards A, and from that foot excavate into the side of the hill, and form with it the lower portion, dotted off, of the embankment, until the 30,000 deficiency is made up, taking care that this base of the embankment is formed of the required width for the depth, and with the proper slope. If the depth of the embankment is here of 20 ft., and the height *c d* is 8, that is 12 below formation, we shall have the following calculation: base 30 + 12 × 2 (ratio of slope) = 54, and twice the ratio of slope will give 78 for the width required along *e g*. We shall not always find the side-cutting so convenient as this; rising ground may be at a considerable distance, which would, therefore, much increase the expense, and it may, in many cases, be better to cut a trench of some breadth a few yards from the foot of the embankment, and wheel the stuff up to the seat; all cases, however, connected with side-cutting and spoil banks vary so much that circumstances alone can direct the best modes of proceeding.

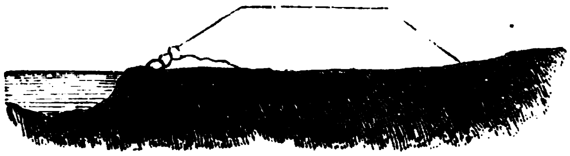
In forming an embankment in sidelong ground, steps should be cut in the seat of the embankment, which should dip at right angles to the batter; and where the ground dips round from the sides to the front in the direction of the tip, these steps should be brought round also. Fig. 10

FIG. 10.



will show how very much the earth would tend to slip under pressure along the natural surface. Where this is neglected, there will not fail to be continual slips, and of a serious nature, from the embankment never becoming firmly seated. Where a bank runs along the edge of a river, stream, pond, &c., the foot of the slope should be pitched with large stones, well bedded at right angles to the batter, and these should be backed up with a foot or two of clay paddle, Fig. 11. Great care should be observed in carrying an embankment over a bridge, or up to the abutment of a viaduct, or there will be considerable risk that the weight of earth will spring up an arch, or overset the abutment. In no case should this be done until the mortar has become perfectly set, and until

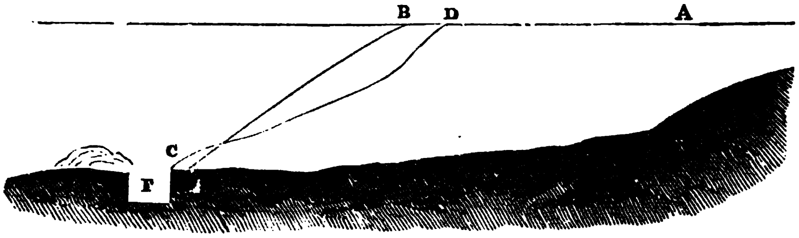
FIG. 11.



the abutment has been well punned up, when the greater mass will deaden the effect of the weight of the earth tipped over. The greatest care will be necessary in carrying an embankment over or near subterraneous works; unless these be at a very great depth, the embankment should be formed in successive layers until some height is obtained, and, during the progress of the embankment, the underground works should be constantly visited, and strengthened where required; an accident under these circumstances occurring in the subterraneous constructions, would be made a source of heavy expense to the company. In passing over mining districts, it is well to make arrangements for giving extra support to the galleries, unless at a great depth, and where the beds have not been worked, to allow compensation for certain portions being left unworked. In carrying an embankment along a retaining wall, attention should be given that the latter be well punned up before the earth is allowed to be tipped along the back of it, and the same remark will hold as regards long and deep wing walls, which, if this precaution be neglected, are very likely to be overturned, or at least disfigured, by being forced out of their intended form.

Either from material in too wet a state having been allowed to be tipped, or from water having accumulated on the seat, it most unfortunately, as well as unnecessarily, happens that the tip will slip not only transversely, but also in length. At Fig. 12, the line A B C shows the tip, as it would have been but for the circumstances just mentioned, instead of which it assumed the form A D C in every direction, nor could the work of fifteen days make any change; at last the trench, F, was cut across the seat of the embankment, and two more cut along the sides; the first determined a more vertical direction for the tip, and the latter trenches drained the seat; by these means the slopes were brought back to a proper state.

FIG. 12.

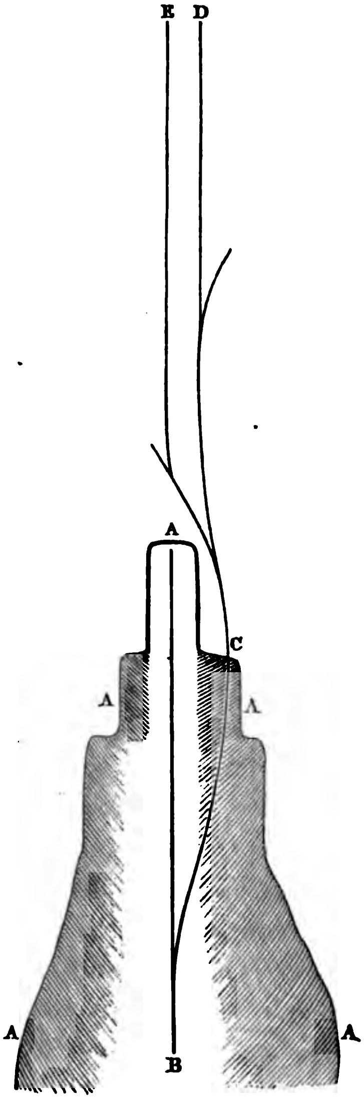


An embankment will generally be formed along the side of a hill, or in a valley, always at a lower level than the approximate land on one side or the other, and, consequently, it will be converted into a dam, which will pen up the rain waters, which, after heavy falls of rain or rapid thaws, will accumulate from the sides of the highest grounds down to the embankment, and greatly endanger the embankment, unless sufficient outlets have been provided. Where streams run under the embankment through culverts, but little more will be required to carry off freshets; but where there is no stream we must increase the number or diameter of the drains, which would, under any circumstance, be required under an embankment, and more particularly if the seat give indications of water; for the position of these the lowest natural levels generally will be selected; on a wet seat no embankment will ever properly settle without assuming a breadth of slope never originally contemplated, and hence the necessity of drains in such cases along the whole length and breadth of the embankment, with good outfalls.

According to the length of lead, the quantities to be excavated, the speed required, and the width of base, the number of tips will be greater or less. There is a usual number, but with more than four the number of wagons and horses are apt to get confused, and thus cause delays rather than speed, though the number and efficiency of the men at the tip, as well as the dexterity of the drivers, will determine much of this; whatever number of tips there may be, care should be taken that the outermost be kept the foremost; the inner tips falling between tend to force a firmer consolidation. Circumstances often occur where it is not desirable to work out the full depth of a cutting at once; such a case would occur where, for some feet above formation line, much water was found; it would be better at first not to excavate below the depth where water is first tapped, providing at the same time ample means of drainage to carry it off from the mouth of the cutting. The remaining depth can be got out afterwards, when the upper portion of the cutting is nearly finished.

A very favourable way of working a cutting of any considerable length and depth is explained in Fig. 13, where A A A A A is the main gullet; the depth below the surface is some 20 feet; proceed to get out at C, so as to form a new road from B to C on to D; the depth excavated from C to D, for a length of 10 or 15 chains, or more, as the case may be, will not at first exceed 2 or 3 feet, the earth being first cast up on the side, the road C D is then got in, and the getting and filling proceeds at this depth of 2 or 3 feet, until we can get in another road at C A E, to which the rails C D are then moved; by means of the trucks on this second road the cutting on either side is then deepened until a depth of 5 or 6 feet is reached, when the rails are transferred back to the old road C D. As this goes on new roads may be struck out on each side of the first two. As this top or second gullet is thus carried on, care is taken to push the work at C, so as gradually to bring down the incline in the top gullet to the level of the main gullet. In this kind of gulleting, the earth is often first "got" by means of a large plough.

Fig. 13.



CHAPTER VII.

SPECIFICATIONS.

The following copy of a Specification, with other details of such matters, given at the end of this chapter, will afford sufficient memoranda as a guide for getting up such documents; remembering, however, that no two cases are exactly alike, though analogous; that every case requires special treatment, according to conditions and circumstances. In this it is always a great help to jot down memoranda as sketches are given and designs worked out, or as special agreements are made as to particular points.

SPECIFICATION FOR A SUBURBAN RAILWAY.

Specification of work necessary for making and completing the whole extent of that portion of the above railway, commencing on the north side of   in the parish of   and terminating at the south side of   in the parish of

The contract is to include all labour, materials, scaffolding, tackle, centreing, moulds, tools, implements, and every other thing necessary for the carrying on and completing the cuttings, excavations, embankments, spoil banks, bridges, retaining and other walls, drains, culverts, raising, lowering, or otherwise altering roads, metalling, and completing the same, streams and sewers, forming temporary and permanent fencing, shoring, needling, strutting, drains of every description, pumping, troughs for carrying off or otherwise taking away water, in conformity with the plans and specifications herewith exhibited, and with such additional drawings and descriptions as may be from time to time furnished while the work is in progress.

The contract extends to a length of statute chains, of 66 feet each lineal, more or less, and comprehends the following works.

The making and erecting the temporary fencing, hoarding, and other enclosures, hereinafter described, and which is to be executed before the commencement of the works.

The forming of the whole of the excavations, embankments, spoil banks, and other earthwork shown upon the plans and sections, or which may be required for the completion of the contract.

The erecting of the bridges over or under the following mentioned roads, ways, streams, &c., with the wing or retaining walls, slopes, and approaches, namely :—

The altering, raising, lowering, or diverting of the present surfaces of the above bridges, and completing the same, as shown in the drawings hereinafter described.

The erecting all the retaining and other walls.

The forming of the drains in the cuttings and embankments, and the diverting, renewing, or otherwise restoring of the existing drains.

The laying of the ballasting for forming of a double line of permanent way, and generally performing every other work either required, or which may be directed to be done for the entire completion of the contract.

GENERAL CLAUSES.

The works are to be conducted under the sole control and direction of the Company's Engineers, and the whole of the materials are to be of the best description of their respective kinds, and the workmanship is to be executed in the best manner; everything necessary being provided by the Contractor, so that the works may be left complete and perfect at the conclusion, to the entire satisfaction of the Company's Engineers, who shall have power to reject any materials or labour which they may deem improper, or to dismiss any person of whom they may disapprove, and the Contractor is to supply such other as shall meet with their approbation. In the event of the non-compliance on the part of the Contractor with these conditions, or of delay in conforming with them beyond one week after receiving a written order, the Engineers are to be at liberty to provide both materials and workmanship, and get the same executed, or appoint overlookers or other persons, and if considered necessary, to dismiss the Contractor from the works, and to complete the same; and the amount of costs which they may decide as incurred, is to be deducted from the amount of contract, and any deficiency in amount is to be paid by the Contractor.

The Contractor is to take upon himself the risk and responsibility of any accidents, damage, or liability, that may occur during the performance of the work, damage to the adjoining lands, buildings, &c., and make good the same at his own expense; and he is also to provide and include in his tender every necessary or contingent expense connected with the construction or formation of the railway, so as to relieve the Company of every liability arising from any cause whatever connected with the works; and the Contractor is to maintain the works complete and satisfactory to the Engineers for a period of twelve months after the opening of the line for public use.

Should any dispute or difference of opinion arise respecting the drawings, specification, measurement, manner of execution, or anything connected with the works, the same shall be decided by the Company's Engineer only, whose decision shall be final and binding on all parties, without reference or appeal to any other person whatever; but if any question as to manner of charge shall arise on the final settlement of accounts, the same shall be referred to arbitration in the customary manner.

In the event of any drawing or description herewith furnished being more in detail than another, the same must be taken to apply to all parts; and any addition, alteration, amendments, reparation, or otherwise, that may be deemed requisite by the Engineers to make the works complete under the contract, the same is to be performed by the Contractor without extra charge.

The works are to be completed within months from the Contractor receiving an order to commence, and a penalty of fifty pounds per day is to be deducted from the amount of his contract from any delay arising from any cause (except the authority of the Engineers) beyond that period.

No temporary works or implements of any kind are to be removed until an order be given by the Engineers for their removal.

The Engineers are to be at liberty to make any alteration or addition to the works they may think proper, without such alteration making void the contract; but this tender is to be accompanied by a schedule of prices according to the following form, at which any additions or deductions are to be valued by the Engineers; but no additions of any kind will be allowed except a written order be produced, signed by one of the Engineers, stating that such extra or addition has been sanctioned by him, and that it does not form a part of the contract (of which they alone are to decide), and vouchers of the quantities must also be produced, signed by the Engineers every succeeding week, certifying that such extra work has been allowed.

All additions or deductions are to be valued at the prices contained in the bills of quantities, which are to be delivered by the Contractor with their tenders; and the prices are to include all labour, materials, and every other thing necessary to complete the works, which are to be measured net, according to the actual quantity when finished; and the cost calculated according to such measurement, and the stipulated prices, without any extra charge for the necessary and contingent work required for their completion, as the Contractor is to include all such charges in the prices which he attaches to the different kinds of work enumerated.

At intervals of every calendar month, as the work advances, payments will be made on account, according to the Engineer's measurements and valuations, in instalments of £90 per cent. on the work actually executed and materials to be used in the work deposited on the ground, such work and materials to be certified by the Engineer in writing, and the balance, less £5 per cent., within two months after the Engineers have certified the whole to be completed to their satisfaction, and the reserved amount twelve months after; if the Engineers find that no derangement of the works or failure has taken place, so that no deduction is to be made on this account.

The Contractor is to produce two persons, who shall be approved by the Railway Company as sureties for the fulfilment of this contract, to the extent of ten per cent. on the amount of his tender.

GENERAL DESCRIPTION OF TRADES.

BRICKLAYER.

The bricks to be used in the several works are to be of the best sound, hard, well-burnt stocks, except such parts as are hereinafter described to be faced, which are to be done with second malm stocks, of an even and bright colour, hard, and well-burnt.

The mortar to be composed of the best stone lime from Merstham, Guildford, or Dorking, and used quite fresh, and clear screened Thames sand, of approved coarseness, mixed in the proportion of one part of the former to three of the latter, guages being kept for the extra measurement.

The brickwork to be laid in a neat close joint worked English bond; all headers to be whole bricks; all cross to be well flushed up with mortar.

No four courses to exceed 12 inches in height.

All work below the level of the ground to be well grouted with hot lime, every course fully flushed up. All work described to be done in cement, or which from its nature must be so executed, is to be laid in equal proportions of Parker's Roman or other approved cement, and clean washed sand, well grouted and fully flushed in with the same in the interior of the work; the whole guaged in as small quantities as possible, and used quite fresh.

All cuttings to raikes, quoins, splays, skewbacks, backings, indents, and other parts required to be performed in the best manner, indents to be made in all cases where new work is connected with old and well pargetted; all arches, whether counter, inverted, or otherwise, to be formed and set in the best manner, and the skewbacks to be carefully cut to the required angle. In all cases where rough counter or inverted arches are directed or required to be made, the same must be done although not specifically described.

The mason and other tradesmen to be attended by the bricklayer, wherever it may be necessary for him to cut away for, or make good after them.

Brick on edge, laid in cement, mixed as above, described to be laid on the top of all walls, where stone coping is not provided for. All arches to be formed in concentric half-brick rings, or in such other manner as may be directed. When the arches are oblique, the bricks are to be laid in accurate spiral lines.

Sewers, culverts, drains, watercourses, channels, &c., are to be constructed with a regular fall according to the drawings at large, and of materials and workmanship as above described. The bricks in each arch of the larger culverts to be well bonded, and the bricks of the arches at the bottom to be quite close at the top edge, and to have an even curvature on the upper surface bedded in mortar and grouted.

The sides to be likewise, where necessary, curved, and one tier of brick keels to be laid in cement along the bottom.

Eyelet-holes for the admission of drains, wherever required, and apertures or shafts 3 feet 6 inches long, and 3 feet in width, the necessary height, 18 inches thick, with stout cast-iron plates or gratings at top, to be placed where shown.

All existing culverts, drains, sewers, watercourses, channels, &c., where crossed or interfered with, are to be preserved, reinstated, or diverted, as the case may be, and all connexion or alterations to be made to the satisfaction of the respective parties having control of the same.

CONCRETE.

When the trenches are excavated to the necessary depth and width, concrete is to be thrown in, composed of one part of lime before described, ground, and seven parts of clean shingle gravel, free from clay and impurities of every kind, and of proportionate coarseness, the whole well incorporated and mixed together with the proper quantity of water, and thrown in from a stage at least 10 feet high from the bottom. All large stones to be broken before being used.

FILLING IN OVER ARCHES AND NEXT WALLS.

The spaces around the tops of arches and backing to all walls to be filled in with dry hard materials, rammed, except where it may be directed by the Engineers to use clay for the backing, in which case the backing or filling in is to consist of the best clay, well worked and beat together, and laid in layers of not more than 9 inches thick, and to be chipped and filled in solidly, so that the work may be impervious to water.

METALLING.

Metalling either of coarse gravel or broken granite, not less than 9 inches thick, and of the proper size, to be laid on the surface of all roads where disturbed, and the footpaths made up of such width and height, and with such materials, as shall be approved. The Contractor will be required to execute all the work connected with the making good the roads to the satisfaction of the road authorities, either as to the kind, quality, and sufficiency of the material and manner of performing the work, or preservation and security of the thoroughfare; providing drainage, both temporary and permanent, so as to relieve the Company from all responsibility as to any alleged insufficiency respecting the public thoroughfares.

MASON'S WORK.

All the stone used in the work is to be Bramley Fall, of the best and most approved description and quality, free from defects of any kind, the whole well worked, bedded, and set, cramped, plugged, and run with lead in all places requisite or directed, although the same may not be particularly described. All to hold their own full dimensions, with parallel beds throughout, and all stones to be of approved lengths.

All holes to be cut or jumped for rails, bolts, and other purposes. All work, where laid on walls, to be set in cement. All coping to be throated wherever projecting, and to have joggle joints run with lead. All clinkstones having eyelet-holes or cast-iron traps to be provided where directed. All bearing stones or strings to be cramped with dovetail cramps, at the joints run with lead, and to be of the sizes shown on the drawing.

No joint will be allowed at a less distance than two feet from the extreme end of every girder, except where moulded corbels are described.

All curb, paving, or pitching removed to be reinstated, or new provided, and laid to the satisfaction of the road authorities.

EXCAVATIONS AND EMBANKMENTS.

The black irregular line drawn on the sections is supposed to represent the natural or present surface of the ground along the centre of the line of railway. And the straight red line shows the bottoms of the cuttings, and the tops of the embankments, immediately under the ballasting necessary for laying the permanent way.

The portion coloured red on the plans shows the site and direction of the railway, taken at the formation level, before the ballasting is laid.

The Contractor will be provided with every facility for erecting the necessary temporary works for his use, and for the deposit or working, and making up of the materials required in such situations as the Engineers will direct.

The figured dimensions on the sections are considered to show accurately the depths of cuttings and heights of embankments, and the contents have been computed according to these dimensions; but should any variations from the results be hereafter found by the Engineers to occur, the value of the variation will be either allowed by the Engineers to the Contractor, or deducted from the amount of his contract, according to the method hereinafter described for ascertaining the value of any variation.

EXCAVATIONS.

The cuttings are to be —— feet wide at the level of the foundation-line, drawn red on the sections, and commencing at —— and terminating at or near ——.

The sides of the excavations are to be formed with a slope, having a base of —— measured horizontal to every one of perpendicular height, and to be dressed fair to this inclination as the cutting advances. The bottom is also to be formed fair and to the longitudinal inclination shown on the sections, with a fall of 6 inches on each side of the centre transversely, and both sides and bottom to be left complete at the conclusion of the works.

At the bottom of each side slope, where brick drains are not provided, a sufficient channel must be formed, 2 feet square with cross drains, and be continued on both sides under all the bridges which cross the railway.

In the event of any water appearing in the excavations, the Contractor is to provide means for excluding the same, whether it arises from draining from the surface, flowing from the land, or from any other cause; so that the excavations in all cases be kept perfectly dry until the completion of the works.

The excavations under brickwork to be made ready to receive the concrete, and to be kept in all cases perfectly dry, the spaces around the concrete and footings to be filled in and well rammed after the brickwork is carried up.

All the embankments and spoil banks, if any, to be properly drained and kept perfectly free from water, and any watercourses or other things interfered with are to be reinstated to the satisfaction of the parties who have control of the same.

The approaches to the roads, whether diverted, raised, or otherwise altered, to be formed according to the inclinations shown on the drawings, or to such other inclinations as will be satisfactory to the road authorities.

The roads to be formed with a proper barrel, made ready for the metalling with dry, hard, or other equally approved material; and the present surface to be either relaid in equal thickness over the whole surface, or new provided and laid of such material as will be approved. The water-channels to be preserved, and the footways, banks, and every other work necessary to make the roads complete in every respect, is to be taken and included in this contract.

FENCING.

The fencing of the roads to be carried on both sides, the whole extent of the slope.

The posts to be of oak, of the best kind, sawed on all sides, 4 inches square, placed 9 feet apart, 4 feet above the ground and 3 feet below, and to have diagonal mortices through to receive the rails.

The rails are to be of fir, 3 inches square, sawed all round, and fixed diagonally, each length passing through two posts alternately, fitted exactly into the mortices of the posts with white lead, and secured with tight screws; the whole to be painted three times with Todd's protoxide paint.

The total collective length of this fencing is to be taken at 500 lineal yards, and is to be fixed where directed.

All fences, hedges, walls, &c., disturbed, to be made good or reinstated in a satisfactory manner at the completion; and wherever the roads are raised or lowered, the ground on each side is to be formed and trimmed to a slope of 1½ to 1, where practicable, or where not, supported by retaining walls.

RETAINING AND OTHER WALLS.

The retaining and other walls and arches are shown and figured in the respective drawings to which they apply.

CONCRETE.

Concrete is to be laid in under the footings of the walls, according to the figured dimensions, and finished with a perfectly level face at top, ready to receive the brickwork.

The retaining and wing walls are to be built with a straight batter of 1½ inches to each foot in height, and the brickwork is to be laid with radiating courses, from a supposed centre, all bonded together, and in all cases the bond must be preserved entire.

No bats except closers will be allowed.

The counterforts are also to be constructed and bonded into the body of the work.

All the walls are to have footings as shown, each course projecting equally before the face of the one immediately over, and sets-off are to be formed horizontally where shown.

The abutments and pier-walls are to be built with a perpendicular face and projecting fascias, according to the drawings and figured dimensions, with footings and sets-off carried round the same, and also round the counterforts.

The parapets are to be built with perpendicular faces on both sides.

ARCHES.

The arches between the girders are to be one brick thick, formed with a regular curve, with bricks carefully selected for the purpose, and laid in cement in the most careful manner, with the proper bond and with neat close joints.

The springings are to be carefully cut and rubbed, so as to abut on all parts on the iron girders.

The soffit of the arches to be perfectly fair, and to be flat-joint pointed when the centerings are removed.

All the walls and backings or filling-in are to be carried up simultaneously, in equal heights, and if unfinished or directed to be suspended, the work is to be carefully protected from any injury from the weather.

Wherever it may be determined by the Engineer to introduce inverted or counter-arches, the same are to be constructed with proper skew backs.

Brick drains are to be constructed in such situations, and laid in such manner, and of such sizes as the engineer shall direct, and the following quantities to be provided and included in this contract; and should any more or less be provided, the same is to be allowed for or deducted, according to the schedule of prices accompanying this tender:

500 feet lineal of 9-inch barrel drain half-brick run.
700 „ 12 „ „ 1 „

set in mortar, and to include all materials—digging, filling in ground, and connexion with existing drains.

Cesspools and larger sizes of drains to be taken at per yard cube, according to the schedule.

Fifty 3-inch tooled York sink-stones, 18 inches square in the clear, with stout cast-iron gratings, each weighing 120lbs., to be provided and fixed over cesspools,

The stone strings, cornices, and other masonry on walls, coloured brown in sections, are to be prepared perfectly true, and according to the drawings, and to be fixed as the walls advance, bedded solidly—no packing-up on the bed side being allowed. The joints are to be the same thickness as those described for the brickwork.

All the strings are to project 1½ inches before the face of the brickwork.

The coping is to be fixed the whole extent of the parapets, to be saddle-backed, projecting 2 inches before each face of the walls, and throated both edges.

All the stone to be fair tooled on all faces, except the back, which is to be made an even face for the brickwork.

No stone to be less than 2 feet in length.

All projections, where not under cover, to be throated.

IRON FOUNDER.

The cast-iron girders are to be of the form and dimensions shown in the drawings. Each girder cast parallel throughout, in one length, and fixed perfectly level and parallel, with an even surface, chipped or filed where in contact with the stone; Oak timber to be used instead of stone wherever ordered by the Engineer. The surfaces where exposed to the eye, or where in contact with woodwork, or forming skew backs for brickwork, are also to be carefully chipped or filed, if necessary, to form an accurately even surface from end to end, and holes must be drilled and countersunk on the face for the reception of the iron tie-rods.

All the girders supporting the rails to be fixed in true parallel right lines where the rails are to be straight on plan, and where curved, so placed as to agree with the proper curvature, and if necessary, or directed, they are to be cast curved on plan, according to a radius which will be furnished by the Engineers.

The tie-rods are to be of wrought-iron, 1¼ inches in diameter, with screwed ends to receive the screw-nuts, which, with the heads, are to be 4 inches square. There are to be three sets of these rods, with head and nuts complete, each to the whole length of every bridge passing under the public carriage roads.

There must also be holes formed ¾ inch in diameter in the flanges of girders, 12 inches apart, to secure the planking where brick arches are not used; and where the double girders are introduced the holes must be formed 1¼ inches diameter, 3 feet apart.

The timbers between the double girders are to be 14 inches by 7, of Dantzic or Memel timber of the best quality, free from sap, large or loose knots, and defects of any kind, to be sawn square all round, and fixed perfectly true with wrought-iron screw bolts 1¼ inch in diameter, with countersunk heads and stout nuts placed alternately on each flange, 6 feet apart.

The intermediate planking is to be laid with 6 inch fir, of the quality and workmanship above described, closely fitted and secured with screw-bolts, having countersunk heads and screw nuts placed 12 inches apart at each end of the separate planks.

A layer of approved stout patent felt with 5lb. sheet lead to be placed under all the longitudinal timbers, beams, on girders.

The cornices and railings of the girder bridges carrying the railway are to be of cast-iron, of the form shown on the drawings, secured to the top flange of the front girder by ⅛-inch screw-bolts and stout nuts and heads 5 feet apart. The whole to be accurately fitted with close joints, cast perfectly true, and of an even exterior surface, preserving the accurate form of the mouldings.

All the cast-iron must be of No. 2 iron, run from cold blast, perfectly sound and true, all to hold the full dimensions, and fixed in such a manner as may be approved, and the girders are to be subject to such tests as the engineers may require, at the Contractor's expense.

No open sand castings will be allowed.

All wrought-iron to be of the best scrap-iron; and any cement joints running in with lead, or other things required to make the iron-work satisfactory in every respect, is to be provided and executed.

Every girder is to be proved at the Contractor's expense, when delivered at the work, to the following tests, which are not to be removed until ordered by the Engineers:—

The girders 15 inches deep to 15 tons in centre.

The girders 24 inches deep to 30 tons in centre.

And should any of them, after these proofs, be considered by the Engineers as unfit for use, the same are to be removed, and such others substituted as will be satisfactory.

All the cast-iron exposed to the eye, and all wrought-iron work, is to be painted three times with Todd's protoxide paint.

SPECIFICATION No. 2.

This Contract comprehends all works, and every operation necessary for the formation of the line of railway as a double line of way from miles chains, shown on the drawing, No. 1, in a field, No. , on the Parliamentary Plan, in the Parish of , in the County of , to miles chains, also shown on the drawing, No. 1, in a field, No. , on the Parliamentary Plan, in the Parish of , in the said County (with the exception of the works in , which will form a separate Contract, and the supply of rails, chairs, and sleepers for the permanent way), and includes also the diversion of the River , and the damming of the present Channel, and the maintenance of the works, including permanent way, for twelve calendar months after the opening of the line to public traffic.

The accompanying drawings referred to in this specification, and in accordance with which the works are to be executed, are in number, as hereunder particularized, and they are strictly to be attended to in the execution of the works, with the particulars and descriptions thereon, as well as such explanatory or detailed drawings which may be furnished by the Engineer during the progress of the works.

FENCING.

The common fencing is to be of that description called post and rail fence (see drawing, No.), with a mound and quick fence and ditch alongside it, and is to extend throughout the entire length of the line, on each side of the same.

The post and rail fence is to consist of posts and four rails; the post to be of Oak or of Larch, perfectly sound, not less than 6 feet long, 4 feet of which must be above the surface of the ground; their dimensions at the smallest end not to be less than 6 inches by 3 inches, and the head of each to be hooped with iron hooping one inch wide, over-lapping at least 3 inches, and fastened by eight 1½-inch nails; they are to be placed not more than 9 feet apart, to be well rammed and firmly fixed in the ground, and each post to have four proper mortice holes for the reception of the rails, the upper one being 5 inches, the second 1 foot 5½ inches, the third 2 feet 5 inches, and the lower one 3 feet 2½ inches; from the top of the posts into these mortices the rails are to be properly scarf-tenoned, so that the scarfed ends may completely fill the mortice, and come at least 3 inches through, so as to be secured by an Oak draw-peg driven through each by the side of the post. The rails are to be of larch, straight and sound, the two upper ones to be not less in dimensions than 4½ inches by 1½ inches, and the two lower ones not less than 3½ inches by 1½ inches. When the posts and rails, as above specified, are firmly fixed and secured, a stake or prick-post is to be driven in the middle of each length, and each rail is to be strongly nailed and clenched thereto. These prick-posts are to be of Oak or Larch, not less than 5 feet 6 inches long, and 8 square inches in section. The fencing is to be placed in such line and situation as shall be set out by the Engineer, and is to be executed in a workmanlike manner, and to his entire satisfaction, both as to workmanship and materials. The post and rail fencing is to be erected immediately after the land is purchased, on any portion of the line, and no other operation is, on any account, to be commenced on any portion of the line which is not fenced in, unless with the special permission of the Engineer. A quickset fence is to be formed within the posts and rails wherever directed, as well as by the side of all return fences; the quicks are to be healthy plants, of three years' growth, set nine in a lineal yard, in a double row. The quicks are to be set in a small bank or mound of good soil, as may be required, but in no case less than shown in drawing, No. . Ditches are to be cut along the whole length of the fencing on both sides of the line, and at such distances therefrom, and of such form and dimensions as the Engineer shall direct; the size given in drawing, No. being the minimum; the bottoms of these ditches are to be formed at such an inclination as shall effectually prevent any lodgment of water. All the fencing is to be maintained by the Contractor until the Contract is complete, and at such completion to be left in a perfect state, and in all respects to the satisfaction of the Engineer; and in all cases in which the fencing shall be injured, broken, or misplaced, it shall be made good and replaced at the sole expense of the Contractor.

OCCUPATION GATES.

Occupation or fence gates are to be provided and fixed by the Contractor wherever required by the Engineer. They are to consist of good sound English Oak, framed and put together in the best style of workmanship, and to be provided with proper fastenings and wrought-iron hinges of the form shown in drawing No. , and they are to be provided with chains and padlocks. The posts to be of Oak, wrought die square above the ground, and left rough below it, and of the form and dimensions shown in manner aforesaid, to be well rammed and firmly fixed in the ground, and the fence made good up to them. The whole to be made and fixed in a manner satisfactory to the Engineer. These gates are to receive three coats of good white oil paint.

GATES FOR LEVEL CROSSINGS.

In all cases of public roads crossed on the level, proper gates of the description shown on drawing, No. , are to be provided, and they are to be erected on both sides of the railway.

All these gates are to be of the best English or American Oak, or Memel fir, of the form and dimensions shown on the drawings, truly framed and wrought fair on all the surfaces, and the arrises to be properly chamfered off. The back style and the top bar to be of Oak, and the whole finished in a workmanlike manner.

The hanging, and other posts of these gates are to be set parallel to the centre line of railway, and at such distance apart so that the larger gates when open shall shut completely across the railway, against the shutting-post of the opposite gate.

These posts are to consist of English or American Oak, of the best quality, and the hanging-posts are to be braced or stayed at the depth below the surface, shown on the drawing, No. , and the holes filled up with concrete, to the satisfaction of the Engineer.

All the gates to be furnished with shooting bolts and locks of an approved description, and the whole to receive four coats of the best oil paint of such colour as the Engineer may direct.

The Contractor must provide and fix all such additional clappingposts as the Engineer may consider necessary for each particular case, with all requisite return or other fencing.

EARTHWORK.

The ground is to be thoroughly cleared of all buildings, timber, and fences, which are to be removed to such places as the Engineer shall direct; the buildings, crops, and fences to remain the property of the Engineer; but the standing timber must be taken by the Contractor at a valuation.

In excavating the cuttings and forming the embankments, the Contractor must strictly adhere to the depths and heights figured (or drawn) on the longitudinal section, and form the slopes to — horizontal to one vertical for the cuttings, and — horizontal to one vertical for the embankments, unless where otherwise directed by the Engineer.

The Contractor to remove and carefully put on one side sufficient top soil from the site of the cuttings and embankments to soil the slopes, when trimmed, to a thickness of at least six inches, measured at right angles to the line of the slope.

The width of the line at formation through all cuttings is to be — feet, and on all embankments — feet in the clear, before the slopes are soiled.

In carrying on the embankments due allowance must be made for settlement, and sufficient width at all times maintained that no additions to the side of any embankment shall at any time have to be made, and where by reason of side-lying ground the embankment may have a tendency to slide, proper benchings shall be cut, according to the directions of the Engineer, to receive the embankment.

In carrying the embankments over any bridge or culvert, which is to be covered thereby, care must be taken, by the use of a temporary bridge or staying, to have the embankment brought up equally on both sides of such bridge or culvert, so that the weight of the earth may be brought equally over all parts thereof at the same time; and should any injury or derangement arise to any bridge or culvert, the Contractor will be required to make good the damage, or rebuild it at his own expense, to the satisfaction of the Engineer.

As soon as a part of an embankment has been tipped, the Contractor shall trim and form such a portion of the same as shall be directed by the Engineer, in order to enable him to judge of the proper allowance necessary for settlement and other causes.

The excavations and embankments, when sufficiently advanced, and, as regards the latter, sufficiently settled, the slopes, except where hereinafter otherwise directed, are to be properly trimmed to the required inclinations, and covered with the vegetable earth laid aside for that purpose.

These slopes are at the proper season to be sown with rye-grass and clover-seeds in the proportion of 1¼ pound of clover seeds, and 3 bushels of rye-grass seeds to one acre. Should the seeds sown fail, the Contractor shall re-sow the same at his own expense.

The bottoms of the excavations are to be trimmed truly to the form shown in the cross sections.

The Engineer will set out the work and give the necessary levels from time to time, the Contractor to find him all necessary chainmen and staff-holders, poles, stumps, or other matters that he may require for the purpose, or for measuring up the work, as well as for conveying his instruments or other apparatus from place to place.

The earth or other material arising from the excavations is to be disposed of, as the Engineer shall direct, in the railway embankments, or, in case of surplus, in spoil banks.

In case the Engineer shall determine to obtain any earth from side cutting, the Contractor must execute such side cutting wherever directed, and in such form and to such depth and extent as the Engineer shall determine, and shall first unsoil and afterwards resoil the whole space whence the side cutting shall be taken in a manner satisfactory to the Engineer, and shall dispose of the earth as directed by the Engineer.

Where it happens that any of the excavation is taken to spoil, the site to be occupied by it must previously be stripped of the turf and top soil as before described for embankments, and when the spoil bank is formed, it must be truly levelled to a proper surface, and on no side present a slope of greater inclination than four to one. The whole surface to be then covered with vegetable earth to the satisfaction of the Engineer.

The bottoms of the cuttings to be trimmed truly to the form shown on the cross sections for the purpose of draining the water from the surface into the side drains and ditches, to be formed at the bottom of all cuttings and embankments of not less dimensions than those shown in the drawings, and as much larger as the Engineer may direct.

The Contractor is to keep all the cuttings free from water, and to construct all such water-courses and drains as may be necessary to preserve the slopes from injury by the action of water during the progress of the works or during the time of maintenance.

A footpath of the width of 6 feet is to be formed and gravelled at every turnpike and other public road, and at any of such roads where there are level crossings, the inside of each of the gate-lodges (which will be built by the Company) is to be filled up with earth to rail level, and a path is to be formed, and a path 5 feet wide is to be formed all round each of the lodges.

The description above given as to cuttings and embankments shall equally apply as to manner of work to all cases of bridges approaches, diversions of roads, occupation roads, or for any other purpose of a similar character, and every matter or thing as above specified, or that shall in the opinion of the Engineer be needful for the proper execution of the work.

EXCAVATIONS FOR FOUNDATIONS.

The excavation for foundations of all bridges, culverts, walls, or other brickwork, or masonry, shall be made of such depth and of such dimensions as the nature of the ground will require, the Engineer to decide in this respect without reference to the drawings; but whatever the depth may be, no extra will be allowed in that respect, and no work shall be commenced in any such excavation until the Engineer shall have inspected and approved the same. The excavations to be, during the progress of the work, kept entirely free from water by pumping or otherwise, and the earth arising from such excavation to be placed in the embankment or other part of the work where the Engineer may direct, and in case no such depository can be found, the Contractor to remove the same from the work entirely; and when the erection, whatever it may be, is completed, the foundations to be filled in and punned round and about the brickwork or masonry, and the top smoothly levelled and made good to the satisfaction of the Engineer.

MORTAR.

All mortar used in this Contract is to be mixed in the following manner:—After the component parts have been mixed by hand, in the proportions hereafter specified, for the various descriptions of work, with the proper quantity of water, the mass is to be passed through a properly constructed Pug-Mill, until the several parts are thoroughly incorporated with one another, after which the mortar is to be ground under edge stones, not less than one ton in weight, hooped with an iron rim. The grinding is to be continued until the mortar has arrived at such a consistency as the Engineer shall approve.

BRICKWORK.

The brickwork to be constructed with the best new, sound, well-shaped, hard-burnt bricks, free from all defects; and mortar made in the proportion of two parts of fresh, well-burnt, good Barrow lime, to three parts of clean, sharp sand, or such other proportions as may be approved by the Engineer, which are to be mixed in a dry state, and well tempered, by being passed through a Pug-Mill, with a proper quantity of water, and used fresh. The best pressed bricks, of an uniform red colour, must be used for all face-work and soffites of arches.

No bricks, lime, cement, or other materials, which are not of a quality satisfactory to the Engineer, shall be used in any part of the works.

The bricks to be well watered before being used, to such an extent as the Engineer shall direct.

The bricks are to be well bedded and flushed with mortar, and to be grouted at every second course with a grout composed of two parts sharp clean sand to one of lime, mixed with a proper quantity of water; and the work must be finished in all outside faces with a neat drawn joint and pointed. The work is not to rise more than one foot in four courses; the whole to be done in the very best manner, and to the satisfaction of the Engineer.

All the arches shall be set in mortar, consisting of one part Barrow lime to one part sharp clean sand, or in Roman cement mixed with equal proportions of clean sharp sand, as the Engineer may direct.

The greatest care must be taken that the work be done in the best manner, with all the voussoir joints properly summered, and the bricks forming the skew-back joints to be cut so as to radiate truly. The bricks at the spandril walls must also be cut so as to fit the curvature of the arch.

The work must be backed up, as it proceeds, with good hard punned clay, at least 3 feet in thickness, brought up in layers of 6 inches each, well punned before the next is laid on, or with such other kind of backing, and to such additional thickness, in particular cases, as may be directed by the Engineer.

The arches of the bridges, viaducts, and culverts shall be covered with boiled gas-tar in the following manner:—the tar is to be boiled for 12 hours, or such time as the Engineer may deem necessary, and laid on hot; the first coat to be rubbed in, and additional coats laid on till a thickness of half an inch be obtained. The tarring is to extend up the inside of all spandril walls, as high as rail level, and is to be carried carefully over the edges of the drain pipes.

The spandrils of bridges and viaducts are to be filled with good hard gravel, or such other material as the Engineer shall approve, well beaten down to such a height as may be necessary to bring it to the proper level for the reception of the ballast.

Hoop-iron shall be used in the foundation of the bridges, viaducts, and culverts, and in all such places as the Engineer may direct.

Rubble drains, 1 foot by 1 foot, will be made at the back of all retaining walls, over all arches, and wherever required by the Engineer, and 5-inch drain-pipes, set in mortar, will be laid therefrom, down the abutments and piers, and let off in such direction as the Engineer may direct.

Should the brickwork of any bridge, culvert, wall, or other erection be executed at such a season as is unfit for pointing the exterior face of the work, or should any joints or bricks be injured by the action of the weather previous to the work being taken off the Contractor's hands, the Contractor shall be bound, at his own cost, to make good the same, and to re-point the face of any brickwork which, in the opinion of the Engineer, shall require it.

CONCRETE.

The concrete shall consist of one part good Barrow lime to one part of sharp clean sand, mixed with a proper proportion of water, and passed immediately through a Pug-Mill, or otherwise thoroughly mixed with an equal quantity of clean gravel, and shall be thrown into the foundations immediately after mixing from proper stages, which are to be erected at not less than 10 feet above the ground approved of by the Engineer, who shall also determine as to the proper state of the concrete for the reception of the brickwork, and no building or work of any kind shall be commenced upon it without his inspection and approval.

WOODWORK.

All timber work to be executed in the best style of rough carpentry, left with sawn faces in all the main scantlings, but wrought perfectly true at all surfaces which are in contact, and all mortices and tenons, housings, homelets, &c., well and truly formed and fitted. All planking to be well and truly laid, close-jointed, firmly spiked, with spikes twice as long as the planks are thick, and two of them at each crossing, and the joints to be all tightly caulked and payed over with tar, as specified for arches. The whole of the other timber work to be payed over with three coats of the best Stockholm tar.

All piles are to be shod with iron shoes of 25 lbs. weight, and to be driven until they will not go ¼ of an inch at a blow with a monkey of a ton weight falling 10 feet, or to such other limit of resistance as the Engineer may direct or approve.

The depth of the piles to towing-path are supposed to average not less than 10 feet below ground line; but whatever depth may be requisite, to be provided by the Contractor without extra charge.

All fir made use of in piles, sills, malings, girders, corbels, struts, ties, beams, braces, wall-plates, plankings, or in any form for any purpose whatever, is to be of the best Memel timber, clean, straight, sound, and free from shakes, sap, and large and unsound knots.

All Oak made use of is to be of the best and soundest English heart of Oak.

MASONRY.

All mouldings, string courses, copings, caps, or other Ashlar work in this Contract, is to be of Bramley Fall stone, of an approved quality, free from flaw or defect, worked full and true to the proper profile, set in mortar of the same quality as specified for brickwork, with all requisite lead cramps, &c. All the joints worked square to the face, and the whole outer surface fair stroke tooled all over.

All string courses and copings are to be properly throated along the entire length of their projecting parts, whether so shown upon the drawings or not. All copings are to be dowelled together and run with lead; no stone to be less than 3 feet in length.

The copings, string courses, imposts, &c., shall be dressed on the ground, near the spot where the same are to be used; and all stones which are chipped or injured by carriage or otherwise will be rejected.

CAST IRONWORK.

All cast-iron made use of in rail standards for towing-path or in any other form, to be of good grey metal, equal to the best London castings, and to be painted four times in oil, and left an approved colour.

WROUGHT IRONWORK.

All wrought-iron, in plates, bolts, nuts, straps, cramps, bars, keys, or wedges, or made use of in any other form or manner whatsoever, in any of the bridges or other works, is to be of the best S. C. crown iron, or such other description of iron as shall in the Engineer's opinion be of equal quality; the greatest care must be taken in any welds that may be required, to insure perfect soundness, and all other workmanship, whether forging or fitting up, must be of first-rate quality.

The heads of all bolts must be forged in one with the bolt, and must be as thick as the bolt is in diameter; all nuts must also be of the same thickness as the bolt is in diameter, and the thread both of nuts and bolts must be well and deeply cut, and must be of such quality as the Engineer shall approve.

All wrought ironwork must be painted four times in oil, and left of an approved colour, or other means of protection taken against rust, as the Engineer shall direct. The upper course of stringing-stones must be connected with iron cramps 1 foot 3 inches in length on top by 2 inches by ½ inch thick, and turned down 2 inches at each end.

ROAD METAL FOR OCCUPATION ROADS.

The metal at all occupation roads is to consist of a layer of good gravel, screened and broken, and of a quality satisfactory to the Engineer, or of stone of a quality he shall approve, broken sufficiently small for each piece to pass through a ring 2½ inches in diameter.

The metalling to be 9 inches thick and 12 feet wide. The ruts are to be filled up from time to time, and the whole surface kept smooth, free from water, and ever in a manner satisfactory to the Engineer, until the completion of the Contract.

BALLAST AND PERMANENT WAY.

The ballast is to consist of clean gravel, of such quality in each case as shall be approved by the Engineer, and is to be laid upon the line and trimmed to the form and thickness shown by the drawings, and the quantity is not to be less than at the rate of 10,000 cubic yards per lineal mile; but if from settlement in the banks, or from other causes, a greater quantity is required to keep the road to its proper level and properly boxed up, the Contractor is to provide the same without extra charge.

The ballast is to be procured by the Contractor at his own cost and charge entirely, both for cost of getting, drawing to, and depositing on the line, and also for all incidental charges of purchase, or hire of land from which it is to be obtained, or the purchase of the ballast from parties possessing beds of it, and all legal or professional charges, and every risk or expense whatever attending upon the procuring of it.

The permanent way to consist of a double line of way, of which the guage shall be 4 feet 8½ inches.

The rails, chairs, and sleepers will be found by the Company, and the rails and sleepers will be delivered to the Contractor at the —— ——, and the chairs will be delivered to him at ——, from which places they are to be removed and conveyed to the line by him, and all cost attending their delivery from vessels, trucks, wharf, or railway station, to the Contractor, and of their conveyance to the line to be borne by him, and the Contractor is to be responsible for the quantity of materials delivered to him, and shall make good at his own expense all such as may be rendered unfit for service, and also any deficiency that shall exist at the time of the completion of this Contract.

With respect to the delivery of the rails and chairs to the Contractor, it must be distinctly understood by him that he must be at all and every expense of the delivery, which the parties supplying them are not bound by their Contracts to pay; and, in case he do not provide a sufficient number of men, boats, trucks, or other means to receive them from the sides of the vessels or trucks, or from the railway station upon their arrival, and carry them away immediately, he must be liable for all demurrage or other charges that may be incurred thereby.

The sleepers will be delivered to and put into the boats of the Contractor at a wharf at ——.

The fastenings are to be provided by the Contractor, and are to consist of Ransome's and May's Patent Compressed Wedges and Trenails, as on the other portions of the Great Northern Railway.

The rails and sleepers are to be laid in strict conformity with the cross-section in Drawing No. 5, in the manner hereinafter described.

Previous to laying the rails, the sleepers must each be planed true, and "out of winding," quite across, for a space of 18 inches in length at the seating of each chair, and one trenail hole bored in each for one of the chairs, the boring of which hole is to be done by a machine for the purpose, to ensure due accuracy in its position.

After having been planed and bored, the sleepers are ready for being laid.

The sleepers, rails, and chairs being distributed along any ballasted portion of the line, and the fastenings ready in dry boxes or casks, the operation of plate-laying is to commence by setting out and spacing the joint sleepers and laying them square across the line in proper trenches made in the ballast; one joint chair is then to be trenailed down with one trenail in the hole previously bored, which being done in several sleepers, the rails are then to be laid in the joint chair so trenailed down, their ends adjusted to the middle of the chair, and the distance piece of sheet-iron or copper introduced; the joint wedge is then to be driven to confine the ends of the rails in the joint chairs along one line of rails. Whilst this is in progress, the joint chairs are to be placed upon the planed surface at the other end of the sleeper, as near as may be in their true position; the rails to be introduced as before adjusted to situation and distance of ends, and the wedges driven, the two lines of rails being thus laid on the joint sleepers, one line being fixed with single trenails, it now remains to bore and drive a single trenail in the other line of joint chairs, and thus fix the line in guage. To do this, wrought-iron distance-guages, each having been approved, tested, and stamped by the Engineer, are to be fixed upon both lines of rails, square across near the joint; the hole is to be bored through the inside hole of the chair for the trenail, which, on being driven, fixes down the chair firmly with the rails in perfect guage, the distance-guages not being taken off till the trenails are driven.

Whilst this part of the operation is going forward with the joint sleepers and chairs, and the rails fixed in place, the distances are to be spaced out for the intermediate sleepers, and the sleepers introduced under the rails and squared, those next on each side of the joint sleeper to be 1 foot 6 inches from the centre of each to the centre of the joint sleeper; the rest of the sleepers to be 3 feet from centre to centre, the chairs are then to be well bedded to the sleepers, in all cases free from dust or sand between them and the sleeper.

The chairs at the bored-holes to be trenailed fast down, the wedges driven, the opposite chairs wedged, the distance-guages put on, the sleepers truly adjusted, the inner holes bored, and the trenails well and carefully driven with a proper hammer and drift, to prevent splitting the head, and no split or broken trenails to be left in or admitted to pass, but to be drawn, or re-bored, and a fresh trenail driven; the guages may then be taken off, the remaining trenail holes bored, and the trenails driven as before.

The rails, chairs, and sleepers being all adjusted and fastened, every sleeper is to be well and soundly under-packed with ballast from its lower edge to its upper surface, so as to bring the upper surface of the rails into perfect line and level; and the spaces between them and outside the rails to the extent of the ballast to be well filled in, and boxed up to the underside of the upper flanch of the rails at their outer edge, that is, within one inch of the top of the rails, and neatly trimmed off in such manner and form for drainage as shall be directed by the Engineer.

The Contractor will be allowed to draw ballast along the permanent way; but in so doing care must be taken to keep the sleepers well covered with ballast, so as to protect them from injury in such a manner as shall be satisfactory to the Engineer; and should any sleepers be injured from neglect of this precaution, they must be replaced by new ones, furnished by the Contractor at his own cost.

In laying the rails of the permanent way, the Contractor will not, on any account, be permitted to lay the same at any other level than that determined and set out by the Engineer. A system of lifting through the ballast must not be adopted without express permission of the Engineer.

MAINTENANCE.

All the works of the line, the fences, gates, excavations, embankments, viaducts, bridges, culverts, roads, the diversion of the River , and the damming of the present channel, and all other works whatsoever, are to be maintained by the Contractor at his own cost for twelve calendar months after the line is opened for public traffic, in good working order, true, even, well boxed up with ballast, and at the proper level, to the satisfaction of the Engineer, and without any interruption to the traffic; and all materials (except rails, chairs, and sleepers), and all workmanship and labour of any kind whatever, which are requisite for such maintenance of works and permanent way, are to be furnished by the Contractor at his own cost, and the whole of the line and works to be delivered up by the Contractor in such good order and condition as shall be satisfactory to the Engineer; and should it happen that any work of repair or renewal is in course of execution at the expiration of the said twelve months, such work is, nevertheless, to be completed by the Contractor at his own cost.

GENERAL CONDITIONS.

The Contractor is to execute the whole of the works, and is to provide all plant and materials of every kind that may be requisite (except the rails, chairs, and sleepers for the permanent way), for the due and proper execution of all the works comprehended under this Contract, and he is to take upon himself all risks and contingencies whatever, that may arise in respect of the works; he is to replace and make good at his own cost any works which may fail from whatever cause, whether from bad workmanship or materials, or any other cause.

The various works are to be executed according to the accompanying drawings. These drawings are supposed to be correct, but the Contractor must satisfy himself on this point by taking levels, or by any other means, as no allowance whatever will be made on the ground of any mistake.

If in any case it should happen that the dimensions written or described on the drawing do not correspond with measurements taken by the scales, the Engineer, in all such cases, is to be the sole judge which of the two is correct, and is to be taken, and the work is to be executed according to his decision.

In carrying on the works, the Contractor is to provide, at his own cost, all requisite temporary bridges, coffer dams, crossings, roads, watercourses, and drainage, for keeping up communications and drainage during the progress of the works. The piles driven for coffer dams must not be drawn, but must be cut off level with the bottom of the water-course. Centres must be provided for the whole of the river arches at one time, and for eight of the land arches at each place where they are being turned.

All temporary bridges, crossings, and roads, to be properly lighted and watched, and the Contractor is to be responsible for any damage that may arise in consequence of his not watching, and lighting, and maintaining all such roads, bridges, crossings, &c.

The works are to be carried on under the direction of Mr.
they are to be executed in all respects to his entire satisfaction; and his decision on all questions relating to the works, or to the construction and meaning of this specification, or of the accompanying drawings,

or of any drawings that may be furnished at any time to the Contractor, is to be final and binding on all parties; but in case of the death of Mr. , or his ceasing to be the said Company's Engineer before the Completion of the Contract to which this specification relates, then all disputes relating to the works which may be pending, or which may arise, are to be referred to arbitration.

The Engineer is to have power to alter, vary, add to, or diminish any of the works described or shown by the drawings and specification, or to substitute other works for those shown or specified, and no such alteration, variation, addition, diminution, or substitution, is to vitiate or annul the Contract, but the same to be executed by the Contractor, and to be measured and valued as hereinafter provided for.

The works will be carried on under the immediate charge of a Resident Engineer appointed by Mr. , whose directions on all points relative to the mode of carrying on the works, or to the nature and quality of materials used, or workmanship executed, are to be received and acted on by the Contractor, and he is to have power to reject and condemn any materials and workmanship that he may deem unsuitable; and any workmanship and material so condemned and rejected shall be removed and replaced by the Contractor, at his own cost, to the Engineer's satisfaction; but if in any case the Contractor should consider that the Resident Engineer unnecessarily or unjustly condemns and rejects any workmanship or materials, or should any dispute of any kind relating to the works arise between the Resident Engineer and Contractor, such dispute shall be by them referred to Mr. , and his decision on such difference shall be final and binding on both parties. The work will be set out and also measured for the monthly certificates by the said Resident Engineer, but the Contractor is to provide at his own expense all the materials required for such setting out and measuring, and proper men to assist in so doing, such men being appointed by the said Resident Engineer, but paid by the Contractor.

The Company will provide land for the line, also for depositing spoil earth, and for side cutting (if necessary), but all other land which the Contractor may require for carrying on his operations, or for temporary roads for carrying materials to or from the works, or for other temporary purposes, is to be provided by the Contractor at his own cost. In doing this he will have the assistance of the Company's Parliamentary powers, but all the expenses must be borne by him.

The Contractor will be required, in the construction of every work necessary to the execution of this contract, to conform strictly in every particular to the Acts of Parliament at present in force for carrying out this railway, as well as to all other general Acts in force for the regulation of railways, and to agreements with landowners, and the Company of Proprietors of the River ——— and Canal Navigation; unless under peculiar circumstances he shall have the written permission of the Engineer in chief to depart therefrom.

The Contractor is to be liable, and to be held accountable for all trespass, damage, loss, or injury of whatever kind, that may arise and be sustained by the owners, lessees, or occupiers of land, through or in which the various works under this contract may be in progress.

All works in progress to be carefully watched and lighted at the Contractor's expense, at whatever times and places it may be considered necessary by the Engineer so to do.

The Contractor must, at his own cost, make, form, fence, and maintain whatever temporary roads he may require for bringing any materials or plant to the works, or for any purpose, and no extra charge will be allowed or paid by the Company for, or on account of, any such roads.

No work, except fencing, shall, on any account, be commenced, or any materials or plant be deposited by the Contractor on any part of the line which is not fenced in, unless with the permission of the landowners, lessees, and occupiers whose property may be affected; and even with such permission, the depositing such materials or plant must be entirely at the Contractor's own risk, and he must be responsible for any expenses incurred thereby.

The Contractor, if required, must furnish the Company's Engineer with a statement of the arrangements he proposes to adopt; and in case the Engineer shall consider any alteration in the same desirable, the Contractor shall be bound to conform thereto.

If the Contractor should be delayed in commencing any part of the works, in consequence of the Company not being in a situation to give him possession of any part of the land, or from any other cause arising from the acts or omissions of the Company, an extension of the times of completion shall be made, provided the Engineer shall consider that he is entitled to such extension; and the Engineer shall, in that case, fix the period of such extension, and certify the same in writing under his hand; but no such extension shall be allowed unless application be made in writing by the Contractor to the Engineer, within one month after such cause of delay shall have arisen, whose decision on the subject shall be final and without appeal; and if at any time, in the Engineer's opinion, the progress in any department of the works should be insufficient to ensure completion within the specified times, or such certified extension of times; and if within twenty-one days of his giving notice to the Contractor in writing to that effect, such means of accelerating the rate of progress as shall be satisfactory to the Engineer be not taken by the Contractor, the Engineer shall have power to take the works out of the hands of the Contractor, and on behalf of the Company to carry them on himself, or put them out to other parties to execute; and in so doing he shall have power to make use of any of the working plant and material which, at the time of giving the notice as aforesaid, shall be upon the line; and the Contractor shall be liable for all loss or extra cost which may result from such proceedings.

The Contractor shall not at any time during the progress of the works, or during the term of maintenance thereof, remove any plant or materials from the works without the consent in writing of the Engineer.

The works included in this contract are to be undertaken for a lump sum of money; but should any alteration, addition, variation, or diminution be made to, in, or from the said works, or should other works be substituted for those shown or specified by order of the Engineer, then such altered, additional, varied, diminished, or substituted works to be measured by the Engineer, and to be valued by him at the prices quoted in the Schedule of Prices annexed to the Tender; or if there be no price applicable in the said Schedule, then the price to be fixed by the Engineer, and in all such cases the amount or value thereof to be added to or deducted from the lump sum tendered, as the case may be.

Payments for the works will be made monthly, upon the Engineer's certificate, which certificate will be based upon his estimate of the proportionate value of the works executed, 10 per cent. being first deducted; the amount so deducted is to be retained in the Company's hands, without interest, as a guarantee for the due fulfilment of the contract, and shall be paid over to the Contractor, under the following arrangements, — viz., two-thirds shall be paid over within three calendar months from the date of the Engineer's certificate of the completion of the whole of the works to his satisfaction, and the remaining third shall be paid over within three calendar months of the date of the Engineer's certificate, that the works are in a satisfactory state on the completion of the term of maintenance; but in case of any breach of contract, or failure on the part of the Contractor to perform the contract according to the true intent and spirit of this specification, the said sums so retained in hand shall be forfeited to the Company, or such portion thereof as in the Engineer's judgment shall be equal in amount to any loss which the Company may sustain, in consequence of such breach of contract or failure on the part of the Contractor.

That as a further guarantee for the due performance of the contract, the Contractor is to give the Company a lien on all the plant and materials which shall be placed by him on the line. And in the event of any breach of contract, or failure on the part of the Contractor to perform the contract according to the spirit of this specification, the said plant, or such portion thereof as may be on the line at the time of such breach of contract or failure, shall be available for the Company's use in carrying on the works, or maintenance thereof, in the event of the Engineer finding it necessary to take the same out of the hands of the Contractor, or for the Company to sell such plant or any portion thereof, in order to reimburse themselves for any loss or damage occasioned by such breach of contract or failure.

The Contractor shall at his own cost provide sufficient and decent lodgings for his workmen, navigators, and labourers of every class, at a moderate rent, in all such cases, when, in the opinion of the Engineer, the ordinary means of accommodation in the neighbourhood are insufficient to provide the same, and no huts or hovels will on any account be permitted on any part of the line. The Engineer shall at all times be at liberty to inspect the accommodations which may be provided, and to require the Contractor to make such additions thereto as may seem to the Engineer to be necessary for insuring decency and cleanliness; and if the Contractor neglect, or otherwise fail in having such additions made, then the Engineer shall have power to order such additions to be made by other parties, the cost of which shall be deducted from any moneys due to the Contractor.

The workmen, navigators, and labourers of every class employed upon the line shall be paid their wages in full, in money being the current coin of the realm, at least once in every fortnight, and no ticket or other system of payment by provisions, liquors, or goods, will, on any pretence whatsoever, be allowed; nor shall the Contractor oblige his workmen, navigators, or labourers to take provisions, liquors, or goods from any person appointed by him.

The workmen, navigators, and labourers shall be paid upon the line, if it be possible, or in some building adjoining, and in no case at a public-house, or other place where liquors are sold.

If any person in the employment of the Contractor, in any capacity whatever, conduct himself in any improper manner, or behave with insolence to any officer of the Company, he shall, on the proper representation of the circumstance to the Contractor, be dismissed by him.

No work will, on any account, be allowed to be carried on upon Sundays, unless, in the opinion of the Engineer, the safety of the works requires it.

The Contractor shall have an agent upon the line, together with a sub-agent, who shall represent the Contractor in his absence, and no such agent and sub-agent shall be at the same time absent from the works, upon any account, without the permission of the Engineer. All instructions given to the agent or sub-agent shall be considered as given to the Contractor.

ADDITIONAL DETAILS OF SPECIFICATIONS.

PERMANENT FENCING.

The permanent fencing may consist of a brick wall, of which materials, dimensions, footings should be given, by drawings figured; and whether set in mortar or cement, or in part.

WALL FENCING.

Or it may consist of a rubble wall, set in mortar, with half hammer-dressed coping, according to drawings and dimensions. Where through stones or bonders are to be introduced, it should be mentioned, and the size of the stones limited, both for the walling and coping.

POST AND RAIL FENCING.

Permanent fencing may also consist of a good set fence and ditch, with a row of posts and railing fixed on the outside, according to dimensions to be given. The posts and railing to be provided by the Company, or by the Contractor, according to stipulation; the place for delivery to be appointed, and also the time, and the railing to be fixed as soon as the Contractor is put in possession of any of the Company's lands. The Contractor must be responsible for the whole of the posts and railing from the time of delivery; and, in order to prevent disputes, he must appoint some person to count the same, along with another person to be appointed by the Engineer, and give a receipt for the quantity so delivered on each occasion; and in the case of any portion thereof being lost, broken, or injured after that period, the Contractor must make good the same, and if he should allow any of the posts and railing to remain where it may incur any charge, the same to be paid by the Contractor.

DIMENSIONS OF POSTS AND RAILING.

The posts and railing to be good oak or larch; the posts to be 6 inches square, or 6 by 3½ inches, 3 feet 6 inches out of the ground, and 1 foot 6 inches in the ground; that part below the ground to be well charred, and the posts to be from 7 to 9 feet apart. The scantling of the rails to be 3½ inches by 1½ or 2 inches, and the rails to be properly morticed and fixed into the posts, so that the chamfers at the ends correspond and fit to each other A prick post or stay must be firmly driven down midway between the posts, and this prick post must be 5 feet long and 3 inches by 1½, and each rail firmly nailed to it.

THE COP.

The soil underneath the cop must be carefully trenched over 12 inches deep, previously to the cop being formed; the cop must then be formed by a ramparting of sods on each side, and the intervening space filled with good vegetable soil; the cop must be planted in the months of October or November, February or March, with good white-thorn plants four years old, having been transplanted from the seed bed three years. They must be planted in a row, 9 inches apart, and must be carefully wed, and the soil loosened in the months of May and August in each year. At every intersection of an existing fence, the cop must be continued across the railway ditch, and a sufficient drain put under it to carry the water along the ditch.

DITCH.

The ditch to be 4 feet wide at the top, and 2 feet at the bottom, and 1 foot 6 inches deep; the depth of the ditch must be varied, so as to carry off all the water flowing from the embankments or adjoining lands, and proper communications must be made with each intersected drain, so as effectually to attain the desired object, and drains must be formed under the cop, at such intervals as may be requisite to carry off all the water from the foot of the embankments. The water must be discharged into the nearest existing watercourse; but if, in the opinion of the Engineer, it should be more advisable in any case to carry it down the slopes of an excavation, the Contractor must for that purpose form a sufficient wooden trough of 3-inch planks, properly put together with white lead, and stayed and coursed with tar, without any extra charge. The fence, hedge, and ditch, disturbed during the progress of the works, must be properly reinstated and replanted.

GATES.

Gates, unless otherwise specified, must have 12-inch square posts firmly fixed in the ground, well charred at the ends; the framing shall be well and properly put together; there shall be five horizontal, and two diagonal bars, 6 inches by 3 inches, and two verticals 5″ × 5″; the whole shall be of good sound oak; it shall be hung on proper strong gate-hinges, and shall have a proper spring catch and staple; the whole to be properly painted, two coats lead colour. Dimensions to be shown by drawings.

EXCAVATIONS AND EMBANKMENTS. GRADIENTS.

It is intended that the whole of the excavations and embankments shall be 30 feet wide at the level of the red line on the section, being the underside of the ballast. The rates of inclination of each are to be figured on the section, according to the ratio of the base to the perpendicular, the greater number, in all cases, denoting the length of the base, and the lesser ones the perpendicular heights.

EXTRA LABOUR.

If the Engineer should deem it necessary to increase the width of the excavations or embankments, or to flatten the slopes, the Contractor will be paid extra for increased quantities, unless it happen that there is excess of excavation, which would otherwise have to go to spoil, in which case the Engineer may direct the embankment to be increased without the Contractor being paid any extra sum, or, unless side cutting be required, in which case the Engineer may direct the excavation to be increased, and the Contractor shall have no claim for so doing.

SOIL ON SLOPES.

As the excavations proceed, and the embankments become consolidated, the slopes must be carefully trimmed to the specified inclination, and covered with soil 6 inches thick, for which latter purpose a sufficient quantity of sod must be taken off the tops of the excavations or seats of the embankments, and laid in suitable situations for being put on the slopes. If any deficiency exists, the quantity deficient must be provided by the Contractor at his own expense.

SLOPES TO BE SOWN.

At the proper season the slopes must be sown with rye grass or white clover seeds, at the rate of 2 bushels of the former to 6 pounds of the latter per statute acre.

CHANGE OF INCLINATION.

Whenever any change is made in the inclination of any of the slopes, it must be done gradually, and in not less than 25 yards in length, unless it occur at a bridge, in which case the inclination of the slopes may be different at each side of the bridge.

FORM OF ROAD.

The tops of the embankments, and the bottoms of excavations, must be carefully formed, with an inclination from the centre to the sides of the embankments, and the edge of the side ditch, in the excavations being 10 inches lower than the centre, which latter shall be formed at the level indicated by the red line on the section. Care must be taken that the surface be made perfectly uniform previously to the ballast being laid on, so that no water can possibly lodge in the ballast. Care must be taken that the outside of the bottoms of the excavations and tops of the embankments are formed exactly as marked out on the ground, and shown on the general plan.

Should peat or any other materials be found in any of the excavations which the Engineer may deem unfit to be used in embankments, it must be carried to spoil, and any deficiency which may thereby be occasioned, must be provided for by the Contractor at his own cost.

During the progress of execution, great care must be taken to prevent water from settling in the excavations and embankments, and any means deemed fit by the Engineer must be resorted to in order to prevent it. A ditch, or channel, 12 inches wide and 6 inches deep, must be formed along each side of the excavation, at the foot of the slope, to carry off the water; and if, in the opinion of the Engineer, it should become necessary or advisable, in any one case, to put open drains, formed with rubble pitching and side walls, as shown on drawing, the Contractor shall be paid extra for such increase of work, according to the prices set forth in the schedule.

In the event of any soaks, springs, or streams of water appearing from the face of the slopes or otherwise, the Contractor must, at his own expense, effectually drain the same, by means of drains or watercourses, of rubble or brushwood, put in such manner, and to such extent, as the Engineer shall deem expedient from time to time, to prevent such soak, spring, or stream from injuring the works during progress; and the whole of such water shall be conveyed into proper drains.

Whenever any material occurs suitable for building purposes, the making of brick, or for ballast, the Contractor may make use of the same for the purposes of this contract, if he obtain the written permission of the Engineer, which permission shall specify the purpose for which any such material is to be used, and not otherwise. And if any deficiency be thereby incurred, he must, at his own expense, provide the requisite side cutting to supply such deficiency.

Whenever the seat of an embankment occurs on side-long ground, the same must be cut out in steps, sloping inwards towards the embankment, and the material punned so as to prevent the embankment from slipping. Should the seat of the embankment be peat or other soft material, deemed by the Engineer unfit to bear the weight, the Contractor shall, at his own cost, and according to instructions from the Engineer, remove the same, or cut out a trench, 10 feet wide, entirely through the peat, under the foot of each slope, and fill up the same with good dry material, to be approved of, carrying it 6 feet above the surface of the ground previously to the embankment being tipped on it.

In all cases, unless the Engineer direct otherwise, the embankments must, as nearly as practicable, be formed of the finished heights and widths, due allowance being made for shrinkage. The slopes must be trimmed and soiled as soon as practicable, and great care must be taken to prevent water from lodging on any part of an embankment; and if any cracks appear, they must be carefully punned up to prevent water getting in.

TIPPING ON BRIDGES OR CULVERTS.

In bringing an embankment over any bridge or culvert, the greatest care must be taken to prevent any unequal loading; and any damage caused by neglecting this precaution, must be made good by the Contractor at his own cost. In the case of culverts with side walls, a space of 10 feet on each side, and over the top, must be punned to a height of 8 feet above the culverts, and no greater height of embankment must, in any case, be allowed to be tipped against or upon the culverts than the height already laid upon the culverts. In the case of crossing of bridges in embankments, the earth must be punned in each case for such a space as the Engineer may deem requisite, in no case being for a less space than 10 feet from the abutment or wing wall, and the material must be conveyed across the bridge by means of baulks of timber laid so as to enable each side to be embanked equally at the same time.

TEMPORARY ROADS.

Where the building of bridges may interfere with the traffic of roads, and previous to any bridge works being commenced, a proper, well-made temporary road shall be prepared and made, which must be sufficient for the free passage of carriages of all descriptions. The Contractor must take every precaution, during the alteration, to erect proper fencing, fix lights, and have a night watchman to prevent accidents, as the Company will not be liable for any injury arising from any neglect of these precautions on the part of the Contractor.

BRICKWORK.

The bricks made use of shall be hard, sound, well-shapen, thoroughly burnt, and of uniform size, and, unless made a year before they are used, must be well saturated with water. No broken bricks will be allowed, except where required as closers; and, in case of backing, the whole must be flushed up perfectly solid with mortar, for which purpose, after the outside course is set, the mortar must be laid on the interior space, and must be well spread and worked about until every joint is filled perfectly solid. The whole must be built in old English bond, that is, in alternate courses of headers and stretchers, and in case of thick walls, every third and fourth course of the interior must be laid a "Herringbone;" the face work must all be neatly jointed with a trowel, and struck with a straight-edge. No face work will be allowed to be built over handed; no four courses with three joints must exceed in thickness, when built, three-quarters of an inch more than the same bricks measure when piled on each other without mortar.

BRICK ARCHWORK.

The bricks for all the small culverts, and other small arches, must be moulded to suit the summering of the arches. If, in any case, bricks should be used in the face of skew arches, they must be moulded to the proper angle. The bricks in the arches must be laid with a mallet. The arches are to be backed with solid brickwork up to the height shown in the drawing, and the spandrils are to be carried up with the backing to the same height before the centres are eased, and the remaining or upper portion of the spandrils is not to be built until the centres are eased quite clear of the arches, and all the arches are turned and backed to the height shown on the drawings. All the joints of the soffits must be raked and neatly pointed. After all the arches shall have been turned, and the centres eased or struck, and after such time shall have elapsed as the Engineer shall deem sufficient to ensure no further subsidence in an arch, then the remaining portions of the spandril walls may be carried up to the level of the underside of the parapet.

No brickwork or stonework shall be set in frosty weather.

STONE.

All the stone used in the work should be sound, hard stone, free from shakes, clay holes, beds, or flaws of any descriptions: if desirable, describe the quarry; it must be approved of by the Engineer. No stone either in the inside or outside work should break joint less than 18 inches; the stones in the interior work should bond well with each other, and each course well grouted with lime.

ASHLER WORK.

The ashler work shall lay in courses, not less than 12 inches thick, and with stones, not less than 4 feet by 2 feet on the bed, and laid alternately as headers and stretchers; all joints must overlap at least 12 inches; all the joints and beds of all exterior ashler work must be chisel dressed, and those of the interior must be dressed equally true, but with a pick instead of a chisel, and to be well bedded in the best lime mortar. The faces must be fair tooled, or picked with rustic chamfered joints, as may be directed. In all cases where the Engineer may deem it advisable, the whole must be dowelled together with dove-tailed hard stone dowells, or cramped with iron.*

BLOCK IN COURSE WORK.

The block in course shall be of stone laid in courses, not less than 7 inches thick, and each stone shall not be less than 12 inches by 18 inches on the bed, laid alternately as header and stretcher; and one-fourth the length of each course shall consist of stones not less than 30 inches in length, measuring from the face of the work to the interior, laid as nearly equidistant as possible, so as to effect a perfect bond with the rubble backing; whenever the face work consists of stones larger than the minimum size here specified, the bond stones must be proportionately increased in length. The beds and joints must be carefully hammer-dressed to accurate planes, and the faces pitched; the joints must be dressed square for at least 6 inches from the face. The whole must be laid in mortar, and backed with rubble.

RUBBLE BACKING.

The rubble backing must consist of flat bedded stones, as large as can be obtained. The whole must be carefully pinned and made solid, laid in mortar, and cut to a level surface at every course of the face work; and after the next course of the face stones is laid, the interstices must be completely filled with thin mortar, the mortar being mixed with water, and worked about until every crevice is filled perfectly solid.

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* Though iron cramps are often used, they should not be resorted to without much consideration, as the corrosion of the iron is sure to rend the stone sooner or later, and where the iron is much exposed to atmospheric influence, this will soon occur.

RUBBLE MASONRY.

When rubble is used for the entire work, both on the face and in the interior, the stones must be laid with great care, so as to be perfectly bonded together; no stone must contain less than a cubic foot except when used only for pinning.

PIER POINTS.

Pier points will consist of flat bedded stones, cut into uniform sizes, not being less than 10 inches by 5 inches on the bed, and 3 inches thick; they will be used for turning the smaller arches; must have ashler or block in course quoins. They must be laid in mortar or cement, as may be directed.

MORTAR.

The mortar must consist of fresh-burnt lime, to be approved of by the Engineer, and clean sharp sand, also approved of by the Engineer. The lime must be carefully fallen and mixed dry with the sand, in the proportion of three parts of sand to one of lime, or in other proportions, if wished by the Engineer. They must be well ground together in a proper mortar-mill, to be erected for the purpose, with a proper quantity of water.

MORTAR FOR FOUNDATIONS.

Where desired by the Engineer, in foundations in parts below the surface of the ground, or under water, or parts exposed to wet, to any height desired, the mortar shall be made with hydraulic lime, of a quality that shall meet with the approbation of the Engineer. No mortar which has set, or become hard, will be allowed to be used.

CEMENT.

The cement used shall be patent Lithige, or Earle's cement, or any other desired, but whichever be used shall be of the best quality, and shall be approved of by the Engineer; it must not have more than one part of clean sharp sand to two parts of cement, and these proportions shall be accurately measured; the mixture shall be wetted only as required for use, and none shall be used that has set or hardened.

CONCRETE.

The concrete must be composed of good coarse gravel, or broken stones, either being approved of by the Engineer, with an admixture of good sharp sand. The gravel and sand must be mixed with lime, in the proportion of one part of the latter to six parts of the former. The lime must be ground fine in a proper mill, and not slacked or fallen, and must be mixed in a dry state with the proper proportion of gravel accurately measured. It must not be wetted until it is used. It must then be spread and punned hard at every foot in height, must be grouted with good grout of the consistency of thick cream. The grout shall be composed of quick-lime and a little sand and water, and shall be poured on hot.

ARCHES.

Stone arches will be of ashler, block in course, or pier points. The term ashler is used for cases where the stones exceed 2 feet in depth, or where they form quoins with rustic chamfered joints, or are stepped up to form horizontal beds for the spandrils. The term block in course arch is used for arches where the stones are not more than 2 feet deep, or are not stopped upon the face, or for arches in which the body of the arch is turned in more than one ring. In whichever denomination of work the arch is turned, the beds and joints of the stones must be worked to accurate planes, and the beds in the direction of the radii of the arch. Where ashler quoins are used to brick arches or pier points, great care must be taken to prevent any unequal settlement. The greatest care must be taken to cut the stone in the spandrils so as to fit close on the extrados of the arch.

SKEW ARCHES.

In all cases where the arches are built askew, the courses must be in spiral lines, at right angles to the face of the arch.

PIERPOINT ARCHES.

Pierpoint arches will be laid similarly to brick arches.

COUNTERFORTS.

Counterforts must be worked into the body of the arch, and the courses below the springing of the arch must all be parallel to the radius of the arch at the springing line.

BACKING OF ARCHES.

The backing of arches shall consist of bricks or rubble, laid in mortar, as before described, excepting that bats, or broken bricks, not less than half a brick, may be used in this part of the work. The spandrils, filled in with dry materials, must be drained by means of earthenware pipes, of 9 inches diameter, with spigot joints carried down the piers or abutments, with proper elbows or bends to conduct the water out, and perforated heads over the top.

TAR OR ASPHALTE FOR ARCHES.

As soon as the weather will permit, or when the Engineer may direct, the arch and backing shall be covered with coal-tar in the following manner. The whole of the upper surface of the arch and backing must be freed from all dirt, dust, and loose materials, or any other extraneous matter, by being well swept, or by any other efficient means; and the work being thus cleaned, must be covered with coal tar, prepared and put on as follows. The coal-tar shall be boiled sufficiently, generally ten or twelve hours, to evaporate all the water and ammoniacal liquor, so that when allowed to cool, it will set moderately hard, and without cracking. The coal-tar thus prepared shall be poured upon the work, and well rubbed into the surface of the work with stiff brushes; and after the tar has been well rubbed into the surface and joints of the work, another coat of not less than a quarter of an inch shall be poured on and suffered to cool. After the erection of spandril walls, they must be similarly coated to the extent of 18 inches in height above the arch and backing, and great attention must be given to make perfect the connexion between the coating of the spandrils and that of the arches. Or asphalte, properly prepared and approved of by the Engineer, may be used for this purpose, which is to prevent water from sinking into the arch; and the Contractor shall be held responsible that the arches, backing, and spandrils to the above height shall be made thus impervious.

UPPER COATING TO ARCHES AND METALLING.

Above this coating of tar or asphalte, and as, and when ordered by the Engineer, a coating of sand to the depth of 6 inches shall be laid, and above this, the space must be filled with shivers of stone laid with a regular surface, and lastly, a good road metalling, of a kind approved of, 8 inches thick, shall be laid, and the stones properly broken

STONE IMPOST.

Where stone imposts or springers are used, they must be equal to the full thickness of the arch, besides allowing for the projection, and no stone shall be less than 30 inches in length; where there is more than one arch, at least four stones on every pier shall extend across the whole breadth of the pier. In cases of skew arches, the skew back must be worked out, to suit the oblique direction of the courses.

COPING AND STRING COURSE.

The string course and coping must be of the dimensions and profile shown on the drawings. The string course must not in any case be placed upon an arch in less than one week after the centres are struck, which shall in no case be done without permission of the Engineer. No stone in the coping shall be less than 3 feet in length; the coping shall be fair tooled, the ends or points being worked angular instead of in a straight line, the one being made to fit into the other, 1 inch from a straight line across; the whole of the string course and coping must be throated underneath.

ABUTMENTS, WINGS, PIERS, AND SPANDRILS.

The abutments, wings, piers, and spandrils, must be built plumb or battering, as shown on the drawings, and in case of all wing walls, the courses must be laid at right angles to the plane of the battering face. Openings must be left through the lower parts of all abutments, wing walls, and retaining walls, and dry rubble drains carried up at the back, in order effectually to prevent any water lodging behind the brickwork or masonry.

FILLING IN.

The abutments and wing walls shall be filled into and backed with chipping of stone, as far as they can be procured, clean dry gravel, or suitable material approved of by the Engineer, and to be procured in the neighbourhood; as they are carried up, the filling and backing shall be well rammed with punning malts, in courses not exceeding 18 inches thick.

CULVERTS.

Culverts, under three feet in length, must be carried to the outside of the fencing. Culverts must be built to the necessary angle, and each culvert shall be so placed as to give a free and uninterrupted passage to the water; and whenever the position or direction of a culvert does not coincide with that of the existing course of stream, the course shall be altered to such extent as may be considered requisite by the Engineer to adapt it to the position of the culvert, by the Contractor, at his own cost. They shall be built of materials to be approved of by the Engineer, and such as will stand well in water, and shall be set in good hydraulic lime mortar. The site of culverts may be varied by the Engineer.

FOUNDATIONS.

The foundations of viaducts, bridges, culverts, walls, and other works, must be excavated to such depth as the Engineer may deem requisite, and no masonry or concrete must be put in until they have been examined and approved of by the Engineer. All the water must be effectually kept out during the execution of the works by means of coffer-dams or pumps, or both, and the coffer-dam or pumps, or other machinery, to be provided by the Contractor, and approved of by the Engineer. If it is required to carry the foundations lower than shown on drawings, the Contractor must execute such additional masonry, brickwork or concrete, or piling and planking, according to the schedule of prices, being paid only for such additional work so put in. The vacant places round the foundations must be filled in solid and punned hard. The foundations of culverts shall be cut out as nearly of the size of the culverts as possible; and, wherever required, any soft material must be taken out, and a bed of concrete laid under the culvert. Such additional work to be paid extra. The foundations shall be made of an even and level surface, and well punned when required by the Engineer.

PILE FOUNDATION.

The piles to be of red pine timber, 10 inches square, each pile shod with a wrought iron shoe, weighing at least 18 lbs.; the piles to be driven well home, and at least 2 feet into a solid material, with waling pieces, 12 inches by 10 inches, bolted to them by wrought-iron bolts, to which 3-inch planking shall be firmly spiked.

WOODWORK.

The whole of the timber used in the bridges shall be of the best St. John's red pine or Baltic timber, and the deals from Dantzic, of such lengths as may be required, free from heart shakes, sap, dead knots, dry rot, or any other defects whatsoever, and thoroughly seasoned, having been felled at least two years, and six months out of water. All the trenails used in the bridges shall be of sound English Oak. It must be stacked as soon as brought on the ground, and preserved from wet until used. All the timber must be painted with three coats of good oil paint, at such times as the Engineer may direct. In measuring timber, no allowance to be made for mortices, tenons, &c., but only the net measurement taken; and the workmanship throughout to be good, sound, and firm, and such as shall be approved of by the Engineer.

CAST-IRON.

All castings shall be moulded of a true form, and free from air-holes or other defects, and shall be of correct measured dimensions when ready to be fitted in place. All cast-iron shall be of the best No. 2 iron, re-melted in the furnace, and shall be of a quality approved by the Engineer; no hot-blast iron will be allowed.

TESTS.

Girders shall be subject to be proved by the hydraulic press, under the inspection of the Engineer, and at the expense of the Contractor, according to what the substance and form are calculated to bear, and each girder shall be tested by at least one-half the calculated breaking weight. Or the iron shall be of such strength, that an inch square bar, of 36 inches in length between supports, shall bear a weight of 500 lbs. suspended in the centre. And, should any castings be injured by testing, or prove unequal to the test, others, that shall be satisfactory to the Engineer, shall be provided by the Contractor.

WORKMANSHIP.

All joints shall be made to fit perfectly close and tight, and no cement stopping or plugging shall be introduced; and in all cases where iron rests upon stone, a milled pad must intervene, and the whole must be put together in the best and most workmanlike manner.

WROUGHT-IRON TESTS.

Wrought-iron must be of the best scrap, or No. 3 bar-iron, approved of by the Engineer, and of sufficient strength to bear, without injury, 15 tons per square inch of sectional area.

WORKMANSHIP.

No wrought-iron straps, bolts, or other work, must on any account be hammered when cold, without being afterwards annealed. The bolts to be made so as to fit the holes correctly, after they are seasoned to receive them. All iron work must be painted with three coats of good oil-paint, without being allowed to rust.

GIRDER VIADUCT.

One girder viaduct over the canal reservoir. The details of this work are shown on the drawings. It is composed of four rows of cast-iron girders, supported by cast-iron piles. There will be eight openings or bays formed by two masonry abutments, and seven rows of piles driven across the line 28 feet from centre to centre, each row consisting of four piles placed exactly under each rail, and driven perfectly perpendicular, and one pile at each side driven inclined, so as to act as stays to the superstructure. Transversely on the top of these six piles, a bed-plate will be fixed, having dovetailed seats to receive the ends of the girders.

PILE DRIVING.

The piles must be driven by a ram weighing one ton let fall from a height of at least 10 feet, until they do not move more than one-eighth of an inch by four blows of the ram. When it is found that the piles cannot be driven further than above specified, each pile must be cut off at the exact height required to receive the bed-plates for the girders. The greatest care must be taken that the four centre piles are perfectly perpendicular, and that all the strutting poles are inclined at the same angle.

FIXING BED-PLATES, GIRDERS, PLATFORM, AND RAILS.

The bed-plates must be fixed across the pile-heads, as shown in the drawings. The girders are intended to have about one-tenth of an inch play at the dovetail at each end, to allow for contraction and expansion. The platform is intended to be of two thicknesses, of 3-inch planking laid diagonally and in contrary directions, secured by bolts, bolting down the rails to the upper flange of the girders. The rail intended to be used over this viaduct will be a rail for continuous bearing; the rails will be found by the Company, but the Contractor must provide the bolts; a guard baulk must be fixed along the inside of each rail, according to dimensions shown on the drawings.

ABUTMENTS OF BLOCK IN COURSE AND RUBBLE.

The abutments will be formed of block in course and rubble backing, with tooled ashler coping to the parapets. A course of ashler, 2 feet wide and 12 inches thick, must be laid across the abutments, to receive the ends of the girders.

PALISADES.

The roadway will be protected by plain cast-iron palisades fixed to the planking, as shown on the drawings.

PITCHING TO SLOPES OF EMBANKMENT.

The slopes of so much of the embankment as extends within the water line must be pitched with stones 12 inches deep, and the Contractor will be required to excavate, at his own expense, the side of the present reservoir, to an extent which will give as great a water space as will be filled up by the railway embankment.

GRAVEL ON PLATFORM.

The platform must be covered with fine gravel to the depth of 1½ inch.

TRUSSED BRIDGE.

This bridge will consist of one opening of 40 feet on the square, and will be built at an angle of 65 degrees. The abutments and wing walls will be of block in course and rubble, with ashler coping. So much of the abutment within the canal as extends from 1 foot below the bottom of the canal to 1 foot above the top water level must be faced with ashler, the courses averaging 2 feet 6 inches from the face; a course of ashler must also be laid along the abutment under the trusses, 12 inches thick and 2 feet wide. The superstructure will be formed by three timber trusses, one between the two lines, and one each side of the roadways, and by joists laid across and resting on the tie-beams, and two thicknesses of 3-inch planking, laid diagonally, and spiked to the joists. The whole must have 1½ inch of fine gravel laid over it.

BRIDGE UNDER BOWER'S LANE.

This bridge, marked No. 12 on the general section, is to be constructed 25 feet span in the clear of the abutment walls, measured on the square.

The drawing (No. 18) shows the construction of this bridge, which is to have abutment as well wing and parapet wall, and concrete foundations. The pier caps and coping are to be of brick, and cast-iron girders connected with wrought-iron ties, and brick arches in cement are to be constructed for carrying the roadway.

The roadway is to be raised 7 feet 6 inches, having approaches as shown, and the retaining walls are to be extended a distance of 40 feet on each side, and at each end beyond the end of the wing walls. The whole width of the top of the wall is to be laid in cement.

The roadway is to be constructed with the best and driest materials, selected from the general excavations, having a surface of coarse clean gravel 12 inches thick laid on the surface and pathways when the work is finished. The pathways are to be raised the necessary height with suitable material, and proper channels formed at the sides for carrying off the water, and the whole of the work is to be left satisfactory to the road authorities.

CHAPTER VIII.

FOUNDATIONS, MORTAR, CEMENTS, CONCRETE, PUDDLE.

THE foundation of a building should be such as to bear without compression or giving way the weight of the superstructure; without slipping; without after deterioration from percolating water washing away any portion of it. These natural advantages we may often meet with as soon as the foundation pit is sunk into any of the rocks and earths; and at the same time some of the best of these, under ordinary circumstances, will occasionally offer difficulties. We may meet with loose wet gravel, with rotten clay, with shifting sands, peat, made ground, which require more care and attention. When these things occur to any extent we must have recourse to some artificial foundation, more or less expensive, according to its kind and extent. Such foundations become independent structures, and require study, experience, as well as judgment and ingenuity.

A bed of good gravel, or dry substantial sand, offers a natural foundation, the pit for which only requires careful levelling; the same may be said of sound clay. Clay, however, if exposed, is not only liable to swell or contract from atmospheric influence, but appears also to be often liable to a chemical action, which may be particularly observed in shaly clays. These earths, when first got up, are often hard as stone, but after a time they become soft and slippery. The sooner, therefore, a foundation pit in such rock is got out and filled in again the better, provided always that local circumstances do not require some special treatment. In clays generally it is desirable to sink the foundation pit a few feet, so as to be free from atmospheric influence.

As natural foundations of a sound nature, the following may also be mentioned,—strong loam, chalk, stony soils, free from water, and almost all strata where a dry, sound crust occurs. A bed of loose gravel may often be greatly consolidated by a plentiful grouting of lime and sand. Having excavated to the depth of the footings, the solidity of the bottom of the pit may be tested by a crowbar, to ascertain the soundness of the ground by the *sound* emitted under the blow; if sharp and clear, the substratum is solid and good; but if hollow and dull, the substratum is infirm, in which case we must sink to ascertain the extent of the unsound portion; if this be only for a few feet, a bed of concrete may be thrown into the pit, to within four or five feet of the surface, which will set the matter right. In a case of this kind, we may often counterbalance the expense of the concrete by reducing the depth of brickwork first proposed.

The effect of vertical weight is to compress the substratum, and in the ratio of irregularity in this compression we shall have irregularity of settlement, which tends to fracture masonry or brickwork from some parts sinking more than others; hence the danger when we meet in a foundation pit with a bottom partly of rock and partly of earth; probably, in such a case, the best remedy is to pile through the earthy portion, and lay walings and planking. Sometimes here again, a bed of good concrete carried down over the area of the earthy portion, and raised entirely over the pit to a height of 3 or 4 feet above the level of the rock, may set us right.

A case not unusual is the following:—After sinking 3 or 4 feet we come to a soft substratum, into which masonry would settle; here we should sink to a depth of 6 or 7 feet; over the area of the pit we may drive a number of piles *until* it is consolidated as it were by packing, and over these lay walings and planking, and then a yard deep of concrete; or after the piles are driven, the ground between them may be got up, and the pit nearly filled with concrete, on which we may build with a good breadth of footings. Shifting sands may often be rendered solid by enclosing the area by deep sheet piling. The solidity of the ground and the weight of a superstructure regulate the depth, and therefore the spread of the footings. In brickwork, the projection of each course should not exceed a quarter brick, and the lowermost course should always be double. In this part of the foundation 6-inch landings are often valuable auxiliaries.

As yet we have been alluding to foundation pits free from water, or tolerably so.

Where surface water is likely to make its way in as the pit is excavated, we may often raise a shallow dam round the site, through the length of which a puddle trench may be got in as the dam is raised.

In a case of shallow water, and where we want a support in front of a pit to be excavated, we may have recourse to close sheet piling, either in a single row, or a double row about 2 feet apart; with the help of one or two hand or chain pumps this is often sufficient, taking care to have a few shoring poles always at hand.

M. Margon, a French Engineer, says that a spring may be blocked out in the following manner:—Build up a rubble well from the site of the spring; the water will rise according to the strength of the spring; when it has attained its level, throw in quick setting cement; when this has hardened, the rubble well may be taken down.

CONCRETE.

Concrete is composed of clean gravel* or ballast and fresh-burned stone lime, ground to powder without slaking, well mixed together in a dry state, and only sufficient water added to bring it to the consistency of mortar, and these materials are then turned over once or twice with a shovel. The relative proportions of the lime and the gravel vary, according to the opinions of Engineers and Architects, from 1 of lime and 5 of gravel, to 1 of lime and 9 of gravel.

But the proper method to determine the correct proportions is to ascertain the quantities which will produce the greatest possible condensation; for the least possible quantity of lime required is such as will fill up all interstices between the particles of sand, and between these and the pebbles, and cement the whole of these together; beyond this dose of lime the least possible quantity should be added, the same being unnecessary. Captain Smith, in his excellent translation of *Vicat on Cements*, gives, in an excellent note to § 211, the following method to estimate the voids in masses of stone, gravel, or sand. "A measure is taken, and exactly filled with it" (the stone, gravel, or sand), "and a similar measure is filled with water; part of the water is gradually transferred from the second to the first measure (pouring it over the stones and sand) till it is full. It is then easy to judge by the quantity of water used what proportion the voids bear to the whole bulk of sand, and which will evidently be the same as the ratio of the quantity of water taken from the second measure (to fill them up) to its whole capacity." And a method mentioned by the same author, to ascertain the quantity of increase of sand which may be added to gravel, is to fill a measure with gravel well shaken down, to condense it as much as possible; a similar measure filled with sand, and part of this is by degrees poured on the gravel, which is well shaken, to cause the sand to penetrate and fill up the interstices capable of receiving it, until it is observed that the bulk of the whole augmenting sensibly, shows that the voids are filled up. The quantity of superadded sand can now be measured, and therefore the proportion of additional sand which the gravel is capable of receiving without augmentation of bulk, may be estimated. And as it is allowed, we believe, by all, that the best relative proportion of the stones to the sand is as 2 to 1, that is, 2 of stones to 1 of sand by measure, we can ascertain, without any very great trouble, whether the gravel should or should not be screened. With gravel in these proportions one-ninth of lime is sufficient to form good concrete, if the lime be of good quality; and we know of many instances where good gravel, not Thames ballast, mixed with Aberthaw lime in these proportions, resisted, after two days, a heavy blow.

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* It may happen that granite may be more easily attainable than gravel, when, if properly broken to a size not exceeding a hen's egg, and mixed with proper proportions of sand, lime, and water, an excellent concrete would be produced. *Hard, well-burnt,* and *dry broken brick* may also be used.

It must, however, be observed, that a greater proportion of lime is almost always specified to be used in the preparation of concrete, in foundations of great extent, as 1 to 5, 1 to 6, 1 to 7, 1 to 8. But the quality of the lime used is, after all, the surest guide as to quantity.

It will be readily understood that, from the slaking of the lime during the preparation of concrete, the materials expand, and this is stated to be three-eighths of an inch for every foot in height, and this amount of expansion it retains; nevertheless, "a cube yard of ballast, with the due proportion of lime, will not make a cube yard of concrete;" and the diminution in bulk is about one-fifth, in the proportion of 8 of ballast to 1 of lime; and "30 cube feet of ballast to 3½ cube feet of ground lime with sufficient quantity of water," are necessary to form 27 cube feet, or one cubical yard of concrete. All this entirely depends on the nature of the lime employed.

The materials of which concrete is formed, and their proportions, being now understood, it must be observed that the site for receiving it should be levelled and well consolidated, where it will admit of it; all water should be bailed out or pumped off, mud, slime, or dirt should be removed, and the sides, as well as the bottom of the excavations, should be rendered as firm, clean, and level, as the ground will admit of being made.

The correct proportion of the stones to the sand in the gravel has been already mentioned, as 2 to 1; to this must be added, that clayey gravel *must* be avoided; but *if* used, it should be washed to free it from impurities, and a due portion of clean sand added; the more varied the size of the stones the better, remembering, however, that those larger than a hen's egg should be broken.

The lime used in the preparation of concrete should always be of an excellent quality, such as the Merstham, the Blue lias of Aberthaw, Halkin mountain, Barrow, &c.; and this more particularly as the importance of the concrete increases from its situation. The lime should be fresh-burnt and ground; after grinding, the lime should be passed through a sieve, and again passed through the mill, when it will be fit to mix with the gravel.

The proportions of gravel and lime having been determined on and measured out, they should be most thoroughly blended. When perfectly mixed, sufficient water should be added to bring the whole to the consistency of mortar, and no more will be required, if the mixing has been sufficient. For moderate quantities, two men may be engaged in mixing the dry materials, one to fetch and pour on the water, and two for turning it over once or twice with shovels, and one for filling it into the barrows, when it should be immediately wheeled away along planks to the side of the excavation and shot in; as soon as the barrow-full is shot, one man should level it, and a light quick-handed punner should follow, and ram it closely, but not heavily, to the sides of the trench. This, be it observed, is the reverse of what was done some ten years since. It is, however, found more satisfactory, and in several instances, where the writer has pursued this system, he has found it answer the purpose. The barrowfull first thrown in should not be immediately covered by the next; but by working from side to side, or from end to end, this may generally be accomplished without interruption. As it is absolutely necessary to the firm condensation of concrete that it should be deposited as quickly as possible after the slaking commences, water must only be added to the mixture as it is wanted, and the barrowmen are ready to wheel it away.

We must not, however, lose sight of the fact that hydraulic limes take a longer time in slaking than the rich limes; when, therefore, using any really hydraulic limes, they should be made carefully into mortar before mixing with the other ingredients; and wherever the quantity or the occasion would warrant the expense, this mortar should be ground in a mill.

When using concrete in maritime works, salt water and sea sand may be employed.

Beton is composed of the same materials as concrete, but the preparation of the constituent parts is different, inasmuch as in the manufacture of beton, the lime, always hydraulic, is slaked before it is mixed with the gravel or broken stone. Sand and pozzuolana are constituent parts when broken stone is used; it is laid in blocks, or immersed in cases or bags. A highly interesting paper on this subject will be found at page 266 of the third volume of the *Civil Engineer's and Architect's Journal*, with regard to the employment of beton on a large scale, which has also been most advantageously used in hydraulic works by the French Engineers, who have long closely studied this artificial material.

For mortar the lime should be fresh-burned and ground, and if kept on the works, it should be stored in a perfectly dry place, and the sand should be clean and sharp. Smeaton successfully employed powdered forge scales, sifted from dirt, as also ground siftings of calcined ironstone, called "minion;" 1 part of lias stone lime with 2 of slag from iron foundries, ground to a fine powder between cast-iron plates, forms a cement which indurates slowly to hardness.

But as mortars may be prepared of very different materials to the above, and as they may be often more within the reach of the Engineer than sharp sand, the following close condensation of some of Vicat's valuable practical remarks may be useful, and lead to useful experiments when the beautifully manufactured limes of England or France are unattainable.

By combining the ingredients in the following tables, we obtain mortars which will harden in water, under ground, or in constantly damp situations:—

With the Rich Limes.	With the slightly Hydraulic Limes.	With the Hydraulic Limes.	With the eminently Hydraulic Limes.
The very energetic pozzuolanas, natural or artificial.	The simply energetic pozzuolanas, natural or artificial. The very energetic pozzuolanas, natural or artificial, tempered by a mixture of ½ of sand or other inert substance The energetic arenes and psammites.	The feebly energetic pozzuolanas, natural or artificial. The energetic pozzuolanas, natural or artificial, tempered with a mixture of ½ of sand. The feebly energetic arenes and psammites.	Inert materials, as the quartzose and calcareous sands. Slag, dross, &c.

Tables of ingredients which will constitute mortars capable of acquiring a great degree of hardness in the open air, and of resisting rain, heat, and severe frosts.

With Rich Limes.	With the slightly Hydraulic Limes.	With the Hydraulic Limes.	With the eminently Hydraulic Limes.
No ingredient will effect this.	No ingredient will completely effect this.	Any very pure sands. Quartzose powders. The powders of hard calcareous minerals, or other inert substances.	Any very pure sands. Quartzose powders. The powders of hard calcareous minerals, or other inert substances.

Vicat adds, that the positive language of facts proves that the more exactly we follow out these combinations, the nearer we shall be to obtaining the desired results.

To elucidate these tables, we will now explain, as concisely as possible, this author's meaning of the technical terms in the above tables. Rich limes are those which, by slaking by the ordinary process, may have the volume doubled or more; their consistency, after years of immersion, remains the same, or nearly so, as on the first day, and in pure water frequently changed, they dissolve to the last grain.*

The slightly hydraulic limes will set in 15 or 20 days after immersion, and continue hardening; but the progress of this gradually decreases, particularly from the sixth to the eighth month; and they acquire the hardness of soap after one year's immersion. They dissolve, but with great difficulty, in pure water, and their expansion by slaking varies, but never attains that of the rich limes.

The hydraulic limes set after six or eight days' immersion, and gradually harden. The greatest part of the effect of induration is attained after six months, when it equals that of very soft stones, and water has no longer any action on it. Their expansion by slaking is always small.

The eminently hydraulic limes set from the second to the fourth day after immersion. In one month they are very hard, and quite insoluble. At the sixth month they appear like the absorbent calcareous stones, whose surface may be cut; they splinter under a blow with a slaty fracture, and their expansion by slaking is always small.

In respect to colour they may be all alike, white, grey, mouse-coloured, red, &c.

Sands may be granitic, schistose, calcareous, and are distinguished from similar powders by falling at once to the bottom of water without sensibly disturbing its transparency; when such powder is mixed with such sand, the sand may be termed rich, but it may be freed from such pulverulent particles by washing.

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* Rich limes are supplied by limestone nearly pure, and by the bituminous and fœtid limestones, whilst the limestones containing from 20 to 25 of silica, alumina, magnesia, iron, and manganese, in variable relative proportions, supply the slightly hydraulic, the hydraulic, and eminently hydraulic limes. To detect a mineral composed of rich lime, we may dissolve a small piece in nitric or muriatic acid; and if no insoluble residuum be left, or if that residuum be trifling, we need not experimentalize any further. But to classify the mineral in the other case, it must be reduced to lime, when we may proceed as described above, and by measuring exactly the time it takes to set, we shall obtain a near approximation to its place.

The arene is one of the fossil sands which are distinguishable from virgin sands by having been deposited by water by the partial and secondary revolutions of the globe. The arene is composed generally of quartzose grains, irregular and angular, mingled with clay, yellow, red, brown, and sometimes white, in proportions varying from ¼ to ¾.

The psammites particularly alluded to in this place belong to the primitive schistose formations, and are always found "in situ" in beds or veins; they are slaty, fine-grained, unctuous to the touch, of a red yellow, or brown colour, and produce a clayey paste with water.

Besides the volcanic pouzzolanas, properly so called, which are of a purple red colour, the pseudo volcanic products from the ignition of coal pits are here included under the term, such as tripolis, calcined sandstones, clays, &c. Pouzzolanas are essentially composed of silica and alumina, united by small quantities of lime, soda, potash, and magnesia.

Under the title of artificial pouzzolanas will be included clays, arenes, psammites, and schists properly cleaned, smithy slag, the refuse of combustion of turf and coal, pounded earthenware, and tile and potshards.

"Very energetic" is a term which has been applied to those substances which, kneaded into a clayey consistency with very rich lime, slaked by ordinary process, form a mortar or cement capable—1st, of setting from the first to the third day after immersion; 2nd, of acquiring after one year the hardness of good brick; 3rd, of yielding a dry powder under the spring saw. The natural and artificial pouzzolanas may be "very, simply, or feebly energetic."

"Energetic" substances, under similar circumstances, produce a mortar or cement capable of—1st, of setting from the fourth to the eighth day; 2nd, of acquiring, after a year's immersion, the hardness of a very soft stone; 3rd, of giving a moist powder with the spring saw.

Substances are termed "feebly energetic," which, under these circumstances, produce a mortar or cement which—1st, will set from the tenth to the twentieth day; 2nd, which acquires, after a year's immersion, the hardness of dry soap; 3rd, which clogs under the spring saw. The arenes, psammites, and clays are generally "feebly energetic and rarely energetic."

And a substance is termed "inert" which, combined with proper proportions of rich lime, makes no alteration in the manner of the action of the lime immersed without mixture; sands, properly so called, are inert substances.

Physical characters will not enable us to ascertain with certainty the action of the above substances on rich lime; even the apparent indications of the natural and artificial pouzzolanas are negative, but general appearances of great density and cohesion announce mediocrity.

But we have many chemical tests of easy application which may greatly facilitate a tolerably correct classification in a number of cases, as the action of acids and lime water; and surely in matters of such importance the knowledge gained by these experiments is not unworthy of the student's attention.

Common acids, sulphuric, nitric, and muriatic, even when most highly concentrated, either with heat or cold, are without action upon pure sands, which are chiefly quartzose. The clay of arenes, separated by washing from the sand, and dried and pulverised, set to macerate (steeped) for several days in muriatic acid, parts with a portion of its iron, and from $\frac{1}{10}$th to $\frac{3}{5}$ths of its alumina, and the schistose psammites are in the same position.

A large portion of the oxide of iron, and nearly all the carbonate of lime, when contained in common clays, are dissolved by muriatic acid; but it does not act with like energy upon their alumina, except in certain arenes and psammites. After two or three days' digestion, the quantity dissolved rarely exceeds $\frac{1}{5}$th, and often does not amount to $\frac{1}{10}$th of the whole.

Upon the natural and artificial pouzzolanas the action of the acids varies greatly; whilst some give up a tolerable quantity of iron, and more than half their alumina, even with dilute acids, others are perfectly refractory. Sulphuric acid will rapidly cover some with an aluminous efflorescence, whilst others are unaffected after a month and more.

Quartzose and calcareous sands are unaffected by lime, even in a boiling state; but the arenes, the psammites, and the clays, as well as natural and artificial pouzzolanas, reduced to powder, and thrown into limpid lime water, will decompose it more or less, and, when in sufficient quantity, will reduce it to a state of purity.

"Inert" substances, except the calcareous sands, are generally unaffected by acids, and without action upon lime water.

"Feebly energetic" substances mostly are slightly affected by acids, and restore a very small quantity of lime water to a pure state.

And most of the "very energetic" substances are powerfully affected by acids, and restore a pretty large quantity of lime water to a state of purity.

It may be added, to assist a trial at these experiments, that artificial pouzzolanas may be made by taking either clays, brown or yellow, schistose psammites, arenes rich in clay, or some species of schists, reducing the specimen to powder, and strewing a layer of it on a plate of iron heated between cherry red and forging heat, and stirring the powder continually to effect a uniform calcination. This roasting may continue from 5 to 25 minutes, according to the kind of material; but the conditions of change sought, are that the material should acquire so much cohesion as to be incapable of forming a paste with water; that it should reach its minimum of specific gravity, and maximum of power of absorption, and that it become more subject than before calcination to the influence of weak acids. A portion of the specimens may be tried with acids previous to the calcination of the remainder.

PUDDLE.

Puddle is as great an auxiliary to the Engineer as concrete, and the best definition that can be given of it is in the following words: a mass of earth reduced to a semi-fluid state by working and chopping it about, while just sufficient water is applied, *until the mass is rendered homogeneous, and so much condensed* that water cannot afterwards pass through it.

The best puddling stuff is a rather lightish loam with a mixture of coarse sand or very fine gravel in it; the very strong clays are inferior on account of the great quantity of water which they will hold, and its disposition to shrink and crack as this escapes; anything in the shape of top soil is entirely improper on account of the quantity of roots and vegetable matter it contains.

When a puddle ditch has been dug clear out to its proper depth, about 9 or 10 inches in depth of puddling stuff is thrown in, from which all large stones, sticks, or weeds are carefully picked out; water is then ladled in with a scoop so as to give the puddling a good wetting; if the puddling stuff be stiff or dry, it may then be left for two or three hours, merely giving it another wetting in the meantime if necessary. The puddler may then proceed with his work. Being provided with a stout pair of puddling boots, he begins at one end of the trench, and keeps chopping with his tool, and quite through it, giving his tool a lunging move every time before he withdraws it, so as to let the water into the puddling stuff and stir it right through; if more water be wanted, another labourer supplies it as the puddler works on; this man thus proceeds chopping and trampling over every inch of the ground as he works down the trench until he gets to the end; he then returns and repeats the operation until the stuff is thoroughly worked up. This is ascertained by the tool going with equal ease through every part of the stuff, which it will not do if there are any dry hard lumps.

A proper quantity of water is very essential to this work, and it may often have to be brought by means of a trench from some stream or pond at a distance to the works. When this is necessary, care must be taken to provide the means of carrying the water off when it is not wanted. When the first course has acquired some solidity, it will be time to lay on the second course, which must not be of greater depth than 10 inches; water is then applied, and the puddling recommences, care being taken that the tool at every chop sinks right down through the upper course into the lower one, so, as it were, to bond them together. A trench thus puddled should never be left uncovered so as to dry.

As the puddle is raised, two or three rows of sods or spits of earth should be laid on each side to raise the bank, if the puddle-trench be in a bank, and the slopes are formed gradually on each side by fresh stuff being wheeled up, until the bank is entirely formed, and then the puddle is covered completely up with ordinary stuff until the bank is raised to its proper height.

Where the light loam is not attainable, but only clay, mix sand or fine gravel with it if attainable; if only gravel, screen it so as to get rid of all stones larger than a bullet, mix clay with this if attainable, or chalk where to be had. A great part of the difficulty lies in the *working of the stuff.*

The real value of puddle, properly made and well worked, may be ascertained by any one who has had an opportunity of excavating into it years after it has been formed.

Having pointed out the great advantages of puddle, it will be desirable to say a few words of its disadvantages. This useful building auxiliary is liable to contract from summer-heat, if exposed to it, and therefore requires to be protected from this influence, and it will be the more liable to contraction if much water has been used in the working of it, and if composed of clay. This is one of the reasons why sandy loam is preferred, and in some cases even fine gravel mixed with chalk, or over which a grouting of rich lime is poured as the puddling process is carried on.

As regards the use of cast-iron and concrete in the foundations of bridges, the following remarks by Mr. Page are extracted from Appendix No. 2 in the "Blue Book" on Westminster Bridge:—

"The construction combines all the advantages of foundations on bearing piles made by means of coffer dams, without the expense and obstruction to the waterway which they involve, and which would have rendered their use at Westminster Bridge all but impracticable.

"Round the bearing piles a casing of cast-iron piles and plates is driven to an abundant depth into the bed of the river, and tied together and to the timber piles by wrought-iron tie-bolts.

"Between the piles the bed of the river is dredged to the hard gravel, and the whole space is filled with concrete, so as to form a solid mass.

"In the Westminster Bridge, the piers of which are to have granite facing, the iron plates are stopped at 6 feet below low water, and granite slabs, 18 to 20 inches thick, are substituted for the plates.

"Each pier thus consists of 145 elm bearing piles, driven, on an average, 29 feet 6 inches below low water line, 44 cast-iron piles, 24 feet 9 inches in length, driven 23 feet 9 inches below low water line, and 44 cast-iron sheeting piles, 15 feet in length, driven 21 feet below low water, surmounted by granite slabs, 8 feet by 5 feet, rising to 2 feet above the water.

"The bearing piles are thus 22 feet below the average level of the caissons of the old bridge, and the cast-iron piles and plates respectively 16 feet 9 inches and 14 feet below that level, and, taking the level of the bed of the river in the centre of the arches to be dredged and maintained as low as the bed of the river at London Bridge, the lower edges of the plates would be 9 feet below that bed, the iron piles would be 11 feet 9 inches below it, and the timber-bearing piles 17 feet below it, while at the piers themselves the ground would be 7 feet higher, giving at the piers a depth from the surface of the bed to the edge of the plates of 18 feet.

"In driving the bearing piles into the clay, the degree of resistance specified for each pile was not attained so soon as was anticipated, which accounts for the additional length of the piles beyond what was specified in the contract; and to obtain a greater area of piled surface I thought it advisable to increase the number of bearing piles originally contemplated.

"The elm piles are 14 inches square; they are driven with a ram of 1 ton, or with a steam ram 1½ tons weight, to a depth of 19 feet into the solid clay, and 24 feet into the bed of the river.

"Supposing these piles to bear the entire weight of the structure, they would be ultimately loaded with a weight of 15 tons each, or 12 tons per square foot in the pile.* The following examples of the loads borne by piles proves that this is an unusually small load for the bearing piles in foundations:—

	LOADED WITH		
	Diameter of Pile.	Total.	Per Square Foot.
	In.	Tons.	Tons.
Neuilly	12	47	47
	12	47	47
Orleans (Pine)	12	46½	46½
	12	46½	46½
Hull Docks	10	25	37
London Bridge	...	80	...
Albert Warehouses, Liverpool	...	80	...
New Westminster Bridge	14	15	12

---

* Pressure on each pile in London Bridge = 80 tons.

"It is a well known fact, that the elm piles would bear, without permanent alteration, a compressive force of 200 tons each. As regards flexure, as they are surrounded by concrete, where not in the bed of the river, they cannot be subject to that strain. As regards durability, they will be entirely cased up in materials protecting them from the alternate action of air and water, and in such circumstances timber does not decay, therefore this portion of the pier is incompressible and indestructible.

"The concrete deposited round the piles is formed of gravel and Portland cement; it is of a very dense character, its specific gravity being 2·3, that of granite being 2·66. This concrete rests upon a dense bed of gravel, overlying the clay; and supposing the concrete surface to bear the total weight of the structure and load, independently of the piles, the pressure on each square foot would not exceed $2\frac{8}{10}$ tons; supposing the weight to be carried by the entire surface of the pier, the pressure would be 2 tons per foot superficial upon the bed of clay, which is now subject to a pressure of 6 tons per foot superficial under the piers of the old bridge, and to $5\frac{8}{10}$ tons on the foot superficial at London Bridge, as before stated.

"The exterior of the pier is a solid and continuous facing of cast-iron and granite, closely fitted and bound together, and to the elm piles with strong wrought-iron tie-bolts. The weight upon the granite, after the bridge had taken its bearing, would be 2 tons on the square foot; the crushing weight of granite is 5 tons to the square inch, or 700 tons to the square foot.

"Each cast-iron guide or main pile (15 inches diameter, the metal being 1 inch thick) is driven 12 feet into the solid London clay, and, in reference to the load it has to bear, is incapable of further sinking. Suppose for a moment that the sheet piles have no effect as bearing piles in themselves, but entirely depend on the shoulder which supports them in the main piles, we should then have about 12 tons to be supported on each of the main piles, partly on the top and partly on the sides. And if there were the least tendency to flexure under this small weight, it is prevented by the ties, and by the surrounding strata through which the piles are driven. But, in point of fact, the resistance of the sheet piles from friction, and their absolute strength, is so far beyond the weight they have to bear, that they must, in truth, be also looked upon as bearing piles of great efficiency.

"Now, as to durability, it may safely be asserted that, as regards the mechanical action of water, or moving materials of the bed of the river, cast-iron is indestructible. As regards its chemical action, we have no data to give cause of alarm, but on the contrary, the use of this material is largely spreading in hydraulic engineering; and numerous instances may be given where it forms the sole dependence of the heaviest structures in water. From my own observations of it when exposed to the action of water from the bed of gravel over the London clay, and from water in the plastic clays, a deposit of oxide of iron is formed on the surface, which actually protects the iron itself; and Mr. Mallet, who has made experiments in great detail, states that iron coated with purified gas-tar will last for ages.

"This part of the pier may therefore be fairly considered to be incompressible and indestructible. As regards fracture from unexpected causes, the solidity of the castings, ascertained by severe tests, is such as to leave no reasonable ground for apprehension on this score."

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